Reviews

REVS. 1-358 VOL. 11, NO. 1 JANUARY 1958

GENERAL

Theoretical and Experimental Methods. 4
Mechanics (Dynamics, Statics, Kinematics) 5

MECHANICS OF SOLIDS

Servomechanisms, Governors, Gyroscopics 9
Vibrations, Balancing..... 10
Wave Motions in Solids, Impact.... 12
Elasticity Theory..... 13
Experimental Stress Analysis..... 15
Rods, Beams, Cables, Machine Elements. 16
Plates, Disks, Shells, Membranes..... 16
Buckling Problems..... 17
Joints and Joining Methods..... 17
Structures 17
Rheology (Plastic, Viscoplastic flow) 19
Failure, Mechanics of Solid State... 19
Material Test Techniques..... 20
Mechanical Properties of Specific Materials 21
Plasticity, Forming and Cutting..... 21

MECHANICS OF FLUIDS

Hydraulics; Cavitation; Transport..... 22
Incompressible Flow: Laminar; Viscous.. 23
Compressible Flow, Gas Dynamics..... 26
Wave Motion in Fluids..... 30
Turbulence, Boundary Layer, etc..... 30
Aerodynamics of Flight; Wind Forces.. 33
Aeroelasticity (Flutter, Divergence, etc.). 35
Propellers, Fans, Turbines, Pumps, etc... 35
Flow and Flight Test Techniques..... 35

HEAT

Thermodynamics..... 38
Heat and Mass Transfer..... 40
Combustion 43

MISCELLANEOUS

Acoustics 46
Ballistics, Detonics (Explosions)..... 47
Soil Mechanics; Seepage..... 47
Micromeritics..... 47
Geophysics, Meteorology, Oceanography..... 48
Lubrication; Bearings; Wear..... 49
Marine Engineering Problems..... 49

Books Received, 50

Three-dimensional Stress Concentrations in the Theory of Elasticity, Eli Sternberg, 1

Published Monthly by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Easton, Pa., and edited by Southwest Research Institute with the co-operation of Linda Hall Library.

APPLIED MECHANICS Reviews

Under the Sponsorship of

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS • THE ENGINEERING FOUNDATION • SOUTHWEST RESEARCH INSTITUTE • OFFICE OF NAVAL RESEARCH • AIR RESEARCH AND DEVELOPMENT COMMAND • NATIONAL SCIENCE FOUNDATION

Industrial Subscribers

AMERICAN MACHINE AND FOUNDRY COMPANY • THE BABCOCK & WILCOX COMPANY • CATERPILLAR TRACTOR COMPANY • FORD MOTOR COMPANY • GENERAL DYNAMICS CORPORATION • GENERAL MOTORS CORPORATION • M. W. KELLOGG COMPANY • SHELL DEVELOPMENT COMPANY • STANDARD OIL FOUNDATION, INC. • UNION CARBIDE CORPORATION • UNITED AIRCRAFT CORPORATION • UNITED SHOE MACHINERY CORPORATION • WESTINGHOUSE ELECTRIC CORPORATION • WOODWARD GOVERNOR COMPANY

EDITOR Martin Goland

EDITORIAL ADVISORS H. L. Dryden T. von Karman S. Timoshenko

EXECUTIVE EDITOR Stephen Juhasz

ASSOCIATE EDITORS H. Norman Abramson P. M. Ku J. C. Shipman K. Washizu

ASSISTANT EDITORS D. Callan S. Gardiner L. Graf S. Lechtman F. Salinas D. Wick

PUBLICATIONS BUSINESS MANAGER S. A. Tucker

OFFICERS OF ASME J. N. Landis, *President* E. J. Kates, *Treasurer* O. B. Schier, II, *Secretary*

AMR MANAGING COMMITTEE R. B. Smith, *Chairman* N. M. Newmark W. Ramberg R. E. Peterson E. Haynes H. Vagtborg J. M. Lessells F. J. Weyl

Editorial Office: **APPLIED MECHANICS REVIEWS, Southwest Research Institute, 8500 Culebra Road, San Antonio 6, Texas, U. S. A.**
Subscription and Production Office: **The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., U. S. A.**

HOW TO OBTAIN COPIES OF ARTICLES INDEXED: Photocopy or microfilm copies of all articles reviewed in this issue will be provided on request. Orders should specify the APPLIED MECHANICS REVIEWS volume and review number; should be addressed to LINDA HALL LIBRARY, 5109 Cherry St., Kansas City 10, Mo., and be accompanied by a remittance to cover costs. Where desirable, photocopies and microfilm may be obtained by teletype, using the number KC334 (call numbers of LINDA HALL LIBRARY). Photocopy costs are 35c for each page of the article photocopied; minimum charge, $1.25. Microfilm costs include service charge of 50c per article, plus 3c per double page; minimum order, $1.25. *(Applicant assumes responsibility for questions of copyright arising from this copying and the use made of copies. Copyright material will not be reproduced beyond recognized "fair use" without consent of copyright owner.)*

APPLIED MECHANICS REVIEWS, January 1958, Vol. 11, No. 1 Published Monthly by The American Society of Mechanical Engineers at 20th and Northampton Streets, Easton, Pa., U. S. A. The editorial office is located at the Southwest Research Institute, San Antonio 6, Texas, U. S. A. Headquarters of ASME, 29 West 39th St., New York 18, N. Y., U. S. A. Price $2.50 per copy, $25.00 a year. Changes of address must be received at Society headquarters seven weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Laws: The Society shall not be responsible for statements or opinions advanced in papers or printed in its publications (B13, Par. 4). . . . Entered as second-class matter, January 11, 1948, at the Post Office at Easton Pa., under the Act of March 3, 1897. ©Copyrighted, 1957. by The American Society of Mechanical Engineers.

APPLIED MECHANICS REVIEWS

VOL. 11, NO. 1 MARTIN GOLAND *Editor* JANUARY, 1958

THREE-DIMENSIONAL STRESS CONCENTRATIONS IN THE THEORY OF ELASTICITY

ELI STERNBERG

DIVISION OF APPLIED MATHEMATICS, BROWN UNIVERSITY, PROVIDENCE, R. I.

INTRODUCTION. SCOPE OF THIS SURVEY

STRESS concentrations in elastic bodies—that is, local accumulations of stress—arise in the presence of discontinuities (or near-discontinuities) of various kinds. The principal sources of such disturbances of the stress field are perhaps:

(a) *Geometric discontinuities* or abrupt changes of shape, as represented by holes, cavities, notches, fillets, grooves, and cracks;

(b) *Material discontinuities*, such as those due to inclusions of, or reinforcements by, materials with elastic properties which differ from the elastic properties of the surrounding matter;

(c) *Load discontinuties*, as exemplified by concentrated and by discontinuously distributed surface loads or body forces. In this category we may include concentrations of thermal stress in homogeneous elastic solids due to a discontinuous temperature field, whose effect is equivalent to the action of a suitably chosen discontinuous body-force distribution. Similarly, local intensifications of the stress field in a body, due to discontinuous constraints of the boundary, may equivalently be regarded as the result of appropriate discontinuous surface loads.

The narrow scope of the present survey is confined to the *analytical* treatment of stress concentrations within the *linear* equilibrium theory of *homogeneous*[1] and *isotropic*, *elastic* media. Furthermore, we limit our attention to concentrations of stress which are either *geometrically induced* or owe their existence to *material discontinuities*, and leave out of account problems in category (c). Finally, we are concerned exclusively with *three-dimensional* problems (including axisymmetric problems) and make no attempt to refer to the extensive literature on the two-dimensional (generalized plane-stress or plane-strain) treatment of plane stress-concentration problems; nor is it intended to cope with the comprehensive list of publications devoted to stress concentrations arising in Saint-Venant torsion or in the pure torsion of solids of revolution.[2]

The space problems here alluded to are of particular interest in connection with failure considerations and present considerably greater analytical difficulties than do the two-dimensional stress-concentration problems just mentioned. Moreover, the two-dimensional study of the plane problem is readily accessible to direct experimental methods, and the problem of pure torsion is, in addition, amenable to convenient experimental analogies. In contrast, stress-concentration problems in space—especially those involving internal cavities or inclusions—are less obliging from the viewpoint of experimental stress analysis, despite the substantial advances of three-dimensional photoelasticity in recent years.

THEORETICAL METHODS OF ANALYSIS

It is characteristic of the problem class under consideration that it is ill-suited for approximate analysis. *Direct variational methods* (energy methods of approximation) are highly laborious when applied to three-dimensional problems in general. A difficulty peculiar to their application in the present context stems from the fact that all such methods are, in essence, averaging processes and conform to the governing field equations merely in the sense of some mean; for this reason, they are apt to yield approximations which correctly portray over-all trends of the actual solution but tend to smoothen steep stress gradients and to blurr primarily local effects. Losing sight of local effects in a stress-concentration problem, however, is tantamount to losing sight of the problem. As to *numerical methods of approximation* (e.g. finite-difference methods coupled with iteration or relaxation procedures), their usefulness in connection with three-dimensional problems which involve curved boundaries and steep stress gradients would also appear to be limited.

Exact methods of analysis for three-dimensional problems in classical elasticity theory usually rest upon solutions of the homogeneous displacement equations of equilibrium in terms of harmonic or bi-harmonic displacement potentials (stress functions[3]). Particular solutions of this kind were introduced already by Kelvin (1) and by Boussinesq (2). The earliest complete solution of the general Navier equations, in

[1] In the case of problems in category (b), it is assumed that both the inclusion and the surrounding matrix are individually homogeneous.

[2] Papers on problems in this class will be cited only if they are closely related to investigations which fall within the proper scope of this survey.

terms of *three* scalar *bi-harmonic* stress functions, is apparently due to Galerkin (3), whose results may be regarded as a generalization of Love's (4) solution for the axisymmetric case, as pointed out by Westergaard (5). The completeness of Galerkin's general solution was established by Papkovich (6) who, at the same time, achieved a reduction to *four harmonic* stress functions. Papkovich's form of the general solution, which has proved particularly fruitful, was later independently discovered by Neuber (7); its completeness was proved directly by Mindlin (8). The reducibility of the Papkovich-Neuber solution to one involving merely *three* harmonic stress functions, was asserted in (6) and (7); it was later re-examined by Slobodyansky (9) and by Eubanks and Sternberg (10). We turn now to our main objective, which is a survey of the available literature on the class of problems described earlier.

LITERATURE SURVEY

(A) *Spherical cavity and inclusion.*

The stress concentration around a spherical cavity in a medium which occupies the entire space, has received repeated attention. If the state of stress at infinity is isotropic, the corresponding solution follows from Lamé's (11) solution for the spherical shell under uniform external pressure. The effect of a spherical cavity on a field of pure shear was studied by Larmor (12). The solution appropriate to a homogeneous uniaxial stress field at infinity—which covers the case of an arbitrary uniform field at infinity—is attributed by Neuber (13) to Leon (14)[4]; it was also given (without derivation) by Southwell and Gough (15). This solution was later derived by Goodier (16) who, at the same time, disposed of the problem presented by a spherical inclusion in a medium subjected to uniaxial tension at infinity. Sen (17) treated the cavity in a field of pure bending and Das (18) solved the associated inclusion problem. The solutions to the various cavity problems just mentioned were re-established by Neuber (13) with the aid of the Papkovich-Neuber stress functions, while Sternberg, Eubanks, and Sadowsky (19) re-derived Leon's results in connection with a treatment of the general axisymmetric problem for a spherical shell. An alternative derivation of Leon's solution, on the basis of Love's stress function, is due to Ling and Yang (20).

(B) *Spheroidal cavity and inclusion.*

The problem presented by the stress concentration around a spheroidal cavity in a circular cylindrical shaft, whose axis coincides with the polar axis of the cavity, was considered first by Neuber (13) for loading conditions corresponding to uniform axial tension, pure bending, Saint-Venant bending, and Saint-Venant torsion of the solid (undisturbed) shaft. Neuber's results, which do not take into account the interference between the spheroidal and the cylindrical boundary of the body, represent first approximations if the shaft is of finite radius they are, however, exact solutions for a cavity in a medium which otherwise occupies the entire space and is under the appropriate stress conditions at infinity. The solution corresponding to a uniaxial state of tension at infinity, *perpendicular* to the polar axis of the cavity, was given by Sadowsky and Sternberg (21), whereas the axisymmetric case of isotropic tension at infinity, was dealt with separately by Shapiro (22). Certain of Neuber's results related to the spheroidal cavity were later duplicated in a different manner by Miyamoto (23), (24), (25) and by Ling and Yang (26). Reference (23) also treats a *rigid* spheroidal inclusion in a body subjected to a uniform axisymmetric stress field at infinity. A complete solution for the stress concentration due to an *elastic* spheroidal inclusion, induced by *arbitrary* uniform tractions at infinity, is due to Edwards (27), who also determined the thermal stresses arising from a uniform change in temperature of the entire (composite) medium.

(C) *Ellipsoidal cavity and inclusion.*

Sadowsky and Sternberg (28) determined the stress distribution in an infinite medium with a general ellipsoidal cavity on the assumption that the principal axes of the (uniform) stress field at infinity coincide with the principal axes of the cavity. This solution, which rests on the use of *ellipsoidal* coordinates, is in closed form in terms of elliptic functions and integrals—in contrast to the solutions cited earlier, which involve merely elementary functions. Lurie (29) later indicated an approach to the same problem, using *Cartesian* coordinates. Results contained in (28) were applied by Robinson (30) to a treatment of the associated inclusion problem; he determined explicitly the temperature stresses produced by a uniform heating (or cooling) of inclusion and matrix. Further contributions to the problem of the ellipsoidal inclusion are due to Niesel (31) and to Eshelby (32).

(D) *Plane cracks.*

The problem of determining the stress concentration produced in an infinite body by a plane crack of arbitrary shape, if the faces of the crack are exposed to prescribed normal pressures, was reduced by Michlin (33) to a mixed boundary-value problem in potential theory. Sneddon (34) applied the Hankel transform to the special case in which the crack is circular and the loading rotationally symmetric. Green (35) subsequently approached Sneddon's case more directly and without the limitation to axisymmetric pressures. The stresses around a pressure-free flat elliptic crack in a body which, at infinity, is under uniform tensions perpendicular to the plane of the crack were obtained directly by Green and Sneddon (36); their results follow also from the solution appropriate to the ellipsoidal cavity, given in (28).

(E) *Notch problems.*

Neuber (13) established solutions for the stress distribution due to a hyperboloidal notch. The specific problem considered by Neuber is that of a body bounded by a single-sheeted hyperboloid of revolution whose boundary is free from tractions; he imposed various conditions upon the (finite) stress resultant of the (vanishing) tractions at infinity, corresponding to axial tension, pure bending, pure shear, and pure torsion. Nishihara and Fujii (37) gave an approximate solution for the stresses in a circular shaft which consists of two semi-infinite cylindrical portions connected by a fillet, and is under axial tension at infinity. The stress concentration around a hemispherical pit in a semi-infinite body which, at infinity, is in a state of plane isotropic tension (parallel to the plane boundary) was obtained by Eubanks (38).

(F) *Stress-concentration interference in space.*

Under this heading we list papers concerned with the mutual effect of two or more spherical cavities in an infinite body, and include investigations related to the interference between a spherical cavity and an external boundary. The influence of two spherical cavities of equal size on an infinite medium which, at infinity, is subjected to tractions rotationally symmetric about the common axis of the cavities, was examined by Sternberg and Sadowsky (39); Miyamoto (40), by different means, later considered the same problem on the assumption that the loading arises from a centrifugal field of inertia forces. An approximate treatment of the effect of more than two spherical cavities in a body of unlimited extent was given by Miyamoto (41), (42).

The spherical cavity in the half-space has been the object of several investigations: Das (43) solved the torsion problem corresponding to a concentrated couple at the plane boundary; Gangvetadze (44) dealt with the case of a uniform radial pressure applied to the boundary of the cavity; Golecki (45) treated

[3]A general bibliography on the subject of stress functions in elasticity theory is beyond the scope of this article.

[4]This puplication is not accessible to the author.

the effect of a gravitational body-force field (but failed to meet the boundary conditions for the plane boundary rigorously).

Ling (46), (47) investigated stresses in a circular cylinder with a spherical cavity centered on its axis. He solved the associated problem of pure torsion in (46) and the problem of axial tension in (47). In the latter paper he assumed, on the basis of physical considerations, that the stress-concentration factor tends to unity as the radius of the cavity approaches the radius of the cylinder. Koiter (47) pointed out that this conjecture is erroneous and established the correct limiting value by elementary shell-theoretic means.

(G) *Three-dimensional stress concentrations in plates.*

Plane stress-concentration problems have usually been treated within the two-dimensional theory of generalized plane stress or plane strain which, in general, furnishes merely an approximation to the actual (three-dimensional) solution of the problem. An exception is provided by the stress concentration around a circular cylindrical hole in an infinite plate of arbitrary thickness in the special case of plane *isotropic tension* at infinity. Here, the plane-stress solution, which is immediate from Lamé's (11) results for the hollow cylinder under a uniform external pressure, is the exact three-dimensional solution of the corresponding plane problem.

A variational scheme for the determination of three-dimensional corrections to two-dimensional solutions of plane problems, was given by E. Reissner (49) who, by similar means, later developed an approximate theory for the bending of plates (50). Green (51) obtained a *three-dimensional* solution to the particular plane stress-concentration problem mentioned above for the nontrivial case of *uniaxial tension* at infinity, which Kirsch (52) investigated two-dimensionally. Concurrently, Sternberg and Sadowsky (53) reached an approximate three-dimensional solution of the same problem with the aid of an energy method; their work, however, does not represent a quantitatively adequate treatment of the problem. Later on, Green (54) presented a general analytical scheme, resting on a rigorous satisfaction of the field equations, for the three-dimensional analysis of plane problems and of problems involving bending of plates by edge-tractions. This approach was recently employed by Alblas (55) in a more detailed study of the problem previously investigated in (51) and (52). Alblas, moreover, dealt extensively with the associated bending problem, which E. Reissner (50) had solved on the basis of his approximate plate theory. The same problem had received previous attention by Bickley (56), within the theory of moderately thick plates, and by Goodier (57), from the viewpoint of classical thin-plate theory.

BIBLIOGRAPHY

1 Lord Kelvin and Tait, P. G., Treatise on natural philosophy, Cambridge University Press, 1879.

2 Boussinesq, J., Application des potentiels à l'étude de l'équilibre et du mouvement des solides élastiques, Paris, Gauthiers-Villars, 1885.

3 Galerkin, B., Contribution à la solution générale du probleme de la théorie de l'élasticité dans le cas de trois dimensions, *C.R. Acad. Sci. Paris* **190,** p. 1047, 1930.

4 Love, A. E. H., A treatise on the mathematical theory of elasticity, New York, Dover Publications, 1944.

5 Westergaard, H. M., Theory of elasticity and plasticity, Harvard University Press, 1952; AMR **7,** Rev. 1033.

6 Papkovich, P. F., Solution générale des équations différentielles fondamentales d'élasticité exprimée par trois fonctions harmoniques, *C.R. Acad. Sci. Paris* **195,** p. 513, 1932.

7 Neuber, H., Ein neuer Ansatz zur Lösung räumlicher Probleme der Elastizitätstheorie, *ZAMM* **14,** 4, p. 203, 1934.

8 Mindlin, R. D., Note on the Galerkin and Papkovich stress functions, *Bull. Amer. math. Soc.* **42,** p. 373, 1936.

9 Slobodyansky, M. G., General forms of solutions in terms of harmonic functions to the equations of elasticity for simply and multiply connected regions (in Russian), *Prikl. Mat. Mekh.* **18,** p. 55, 1954.

10 Eubanks, R. A., and Sternberg, E., On the completeness of the Boussinesq-Papkovich stress functions, *J. rat. Mech. Analysis* **5,** 5, p. 735, 1956.

11 Lamé, M. G., Leçons sur la théorie mathématique de l'élasticité des corps solides, Paris, Gauthier-Villars, 1866.

12 Larmor, J., The influence of flaws and air-cavities on the strength of materials, London, Edinburgh, and Dublin, *Phil. Mag. (5)* **33,** p. 70, 1892.

13 Neuber, H., Kerbspannungslehre, Berlin, J. Springer, 1937 (reprinted by J. W. Edwards, Ann Arbor, Mich., 1944).

14 Leon, A., Störungen der Spannungsverteilung, Vienna, 1908.

15 Southwell, R. V., and Gough, H. J., On the concentration of stress in the neighborhood of a small spherical flaw; and on the propagation of fatigue fractures in "statistically isotropic" materials, *Phil. Mag. (7)* **1,** p. 71, 1926.

16 Goodier, J. N., Concentration of stress around spherical and cylindrical inclusions and flaws, *Trans. ASME* **55,** 7, p. 39, 1933.

17 Sen, B., On the concentration of stresses due to a small spherical cavity in a uniform beam bent by terminal couples, *Bull. Calcutta math. Soc.* **25.** 2, p. 107, 1933.

18 Das, S. Chandra, On the stresses due to a small spherical inclusion in a uniform beam under constant bending moment, *Bull. Calcutta math. Soc.* **45,** 2, p. 55, 1953; AMR **7,** Rev. 2119.

19 Sternberg, E., Eubanks, R. A., and Sadowsky, M. A., On the axisymmetric problem of elasticity theory for a region bounded by two concentric spheres, Proc. First U. S. Nat. Cong. Appl. Mech., Chicago, 1951; New York, ASME, 1952; AMR **6,** Rev. 2711.

20 Ling, Chih-Bing and Yang, Kuo-Liang, On symmetrical strain in solids of revolution in spherical coordinates, *J. appl. Mech.* **18,** 4, p. 367, 1951.

21 Sadowsky, M. A., and Sternberg, E., Stress concentration around an ellipsoidal cavity in an infinite body under arbitrary plane stress perpendicular to the axis of revolution of the cavity, *J. appl. Mech.* **14,** 3, p. 191, 1947.

22 Shapiro, G. S., Axisymmetric deformations around an ellipsoidal cavity, (in Russian), *Dokl. Adad. Nauk SSSR* **58,** 7, p. 1309. 1947.

23 Miyamoto, H., Stress concentration around a heterogeneous insertion of ellipsoid in an infinite body I, *J. Japan Soc. appl. Mech.* **3,** 13, p. 15, 1950.

24 Miyamoto, H., Stress concentration around a heterogeneous insertion of spheroid in an elastic body III (Torsion), Proc. First Japan Cong. Appl. Mech., 1951, p. 43.

25 Miyamoto, H., Stress concentration around a spheroidal cavity in an infinite elastic body, *Trans. Japan Soc. mech. Engng.* **19,** 87, p. 60, 1953.

26 Ling, Chih-Bing and Yang, Kuo-Liang, On symmetrical strain in solids of revolution in curvilinear coordinates, *Ann. Acad. Sinica, Taipei* **1,** p. 507, 1954.

27 Edwards, R. H., Stress concentrations around spheroidal inclusions and cavities, *J. appl. Mech.* **18,** 1, p. 19, 1951.

28 Sadowsky, M. A., and Sternberg, E., Stress concentration around a triaxial ellipsoidal cavity, *J. appl. Mech.* **16,** 2, p. 149, 1949.

29 Lurie, A. I., The state of stress around an ellipsoidal cavity (in Russian), *Dokl. Akad. Nauk SSSR* **87,** 5, p. 709, 1952.

30 Robinson K., Elastic energy of an ellipsoidal inclusion in an infinite solid, *J. appl. Physics* **22,** 8, p. 1945, 1951.

31 Niesel, W., Über elastische ellipsoidische Einschlüsse in homogenen Medien, Inaugural Dissertation, Technische Hochschule Karlsruhe, 1953.

32 Eshelby, J. D., The determination of the elastic field of an ellipsoidal inclusion and related problems, *Proc. roy. Soc. Lond. (A)* **241,** p. 376, 1957.

33 Michlin, S. G., Solution of a certain three-dimensional problem in the theory of elasticity (in Russian), *Prikl. Mat. Mekh.* **10;** p. 301, 1946.

34 Sneddon, I. N., The distribution of stress in the neighboruhood of a crack in an elastic solid, *Proc. roy. Soc. Lond. (A)* **187,** p. 229, 1946.

35 Green, A. E., On Boussinesq's problem and penny-shaped cracks, *Proc. Camb. phil. Soc.* **45,** 2, p. 252, 1948.

36 Green, A. E., and Sneddon, I. N., The distribution of stress in the neighbourhood of a flat elliptical crack, *Proc. Camb. phil. Soc.* pt. 1, **46,** p. 159, 1949.

37 Nishihara, T., and Fujii, T., Stresses in a filletted round bar under tension, Proc. Second Japan Cong. Appl. Mech., 1953, p. 79.

38 Eubanks, R. A., Stress concentration due to a hemispherical pit at a free surface, *J. appl. Mech.* **21,** 1, p. 57, 1954.

39 Sternberg, E., and Sadowsky, M. A., On the axisymmetric problem of the theory of elasticity for an infinite region containing two spherical cavities, *J. appl. Mech.* **19,** 1, p. 19, 1952.

40 Miyamoto, H., On the problem of elasticity theory for an infinite region containing two spherical cavities—a rotation shaft with two spherical cavities of the same size, Proc. Fifth Japan Nat. Cong. Appl. Mech., 1955, p. 125.

41 Miyamoto, H., On the problem of elasticity theory for an infinite region containing three spherical cavities, Proc. Sixth Japan Nat. Cong. Appl. Mech., 1956, p. 27.

42 Miyamoto, H., On the problem of the theory of elasticity for a region containing more than two spherical cavities, *Trans. Japan Soc. mech. Engng.* **23,** 131, p. 431, 1957.

43 Das, S. Chandra, On the effect of a small spherical cavity in a semi-infinite elastic solid under stresses produced by a couple on the plane boundary, *Bull. Calcutta math. Soc.* **45,** 3, p. 89, 1953; AMR **7,** Rev. 3827.

44 Gangvetadze, G. G., The half-space with a spherical cavity (in Russian), Inzhener. Sbornik **22,** p. 65, 1955.

45 Golecki, J., Stresses in a heavy half-space weakened by a spherical cavity (in Polish), *Gornictwo* **3,** 6, p. 61, 1956.

46 Ling, Chih-Bing, Torsion of a circular cylinder having a spherical cavity, *Quart. appl. Math.* **10,** 2, p. 149, 1952; AMR **6,** Rev. 785.

47 Ling, Chih-Bing, Stresses in a circular cylinder having a spherical cavity under tension, *Quart. appl. Math.* **13,** 4, p. 381, 1956; AMR **9,** Rev. 1730.

48 Koiter, W. T., An elementary solution of two stress concentration problems in the neighborhood of a hole, *Quart. appl. Math.* **15,** 3, p. 303. 1957.

49 Reissner, E., On the calculation of three-dimensional corrections for the two-dimensional theory of plane stress, Proc. Fifteenth Eastern Photo elast. Conf., 1942, p. 23.

50 Reissner, E., The effect of transverse-shear deformation on the bending of elastic plates, *J. appl. Mech.* **12,** 2, p. 69, 1945.

51 Green, A. E., Three-dimensional stress systems in isotropic plates I, *Phil. Trans. roy. Soc. Lond. (A)* **240,** 825, p. 561, 1948.

52 Kirsch, G., Die Theorie der Elastizitaet und die Bedürfnisse der Festigkeitslehre, *Z. VDI* **42,** p. 797, 1898.

53 Sternberg, E., and Sadowsky, M. A., Three-dimensional solution for the stress concentration around a circular hole in a plate of arbitrary thickness, *J. appl. Mech.* **16,** 1, p. 27, 1949.

54 Green, A. E., The elastic equilibrium of isotropic plates and cylinders, *Proc. roy. Soc. Lond. (A)* **195,** p. 533, 1949.

55 Alblas, J. B., Theory of the three-dimensional state of stress in a plate with a hole (in Dutch), Dissertation, Technische Hogeschool Delft; Amsterdam, H. J. Paris, 1957.

56 Bickley, W. G., The effect of a hole in a bent plate, *Phil. Mag.* **48,** 6, p. 1014, 1924.

57 Goodier, N. J., The influence of circular and elliptical holes on the transverse flexure of elastic plates, *Phil. Mag.* **22,** 7, p. 69, 1936.

"Letters to the Editor" and "Books Received for Review" now appear after the reviews.

Theoretical and Experimental Methods

(See also Revs. 21, 25, 37, 38, 39, 41, 43, 44, 51, 52, 54, 63, 104, 119, 120, 171, 178, 183, 266, 284, 319, 337, 354)

1. Lorenz, I. M., Some methods for the discussion of differential equations of the fourth order; applications to control problems, *VDI-Forschungsheft (B)* **460** 23, 44 pp., 1957.

Paper deals with the solution of equations of the fourth degree, which are characteristic ones of those mentioned in the title. One method consists in transformation until, from the original five terms, four are left and the coefficients of two of them equal unity. The nature of the solution of the resulting equation can be read from a two-dimensional nomogram, analogous to that given by the Wischnegradski method for equations of the third degree.

This method is shown to be unsatisfactory, because, owing to the complicated transformation, conclusions about the original equation can only be made after putting the data from the nomogram into the original form, which causes a great deal of numerical work. When the equation is transformed in such a way that the coefficients of the terms of fourth and zeroth order equal unity, the nature of the solution remains unaltered. Amount of damping, real and imaginary parts of the roots can be presented as function of the three other coefficients. For a series of values of one coefficient, intersections of the three-dimensional diagram are designed. In a given case, numerical results are found by interpolation between the given intersections. Some typical regulator-equations are deduced and solved with these diagrams.

O. Bottema, Holland

2. Malkin, I. G., Present state of Poincare's method and its possible application (in Russian), Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya, vol. 1, Moscow-Leningrad, Izdvo. Akad. Nauk SSSR, 1955, 169–176; *Ref. Zh. Mekh.* 1956, Rev. 4973.

Review of Soviet works on methods of constructing periodic solutions of nonlinear systems of ordinary differential equations on the basis of the small-parameter method suggested by Poincare. N. P. Erugin, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3. Vishik, M. I., Mixed boundary value problems for systems of differential equations containing a second derivative in time, and method of approximation for their solution (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **100,** 3, 409–412, 1955.

4. Erugin, N. P., Periodic solutions of differential equations (in Russian), *Prikl. Mat. Mekh.* **20,** 1, 148–152, Jan./Feb. 1956.

5. Pogosov, A. A., A graphical method of constructing the transitions in dynamic systems described by ordinary differential equations (in Russian), Thesis, Scient. Res. Inst., Ministry of Elec. Engng. USSR, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4215.
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

6. Lebedev, V. I., Equations and convergence of the differential-difference method (method of straight lines) (in Russian), *Vestnik Moskov. Univ. Ser. Fiz.-Mat. Estest. Nauk* **10,** 10, 47–57, Oct. 1955.

7. Bauer, F. L., Method of step iteration and related methods for the solution of algebraic eigenvalue problems (in German), *ZAMP* **8,** 3, 214–235, Mar. 1957.

Two iterative methods of obtaining simultaneously some or all eigenvalues and eigenvectors of a general matrix are discussed, and related to other known methods. If the matrix A is of order n, and m eigenvalues are required, in the first method, which gives only column eigenvectors, one starts with a matrix Γ_0 of m columns with ones along the main diagonal and zeros above. Thence one obtains recursively matrices Γ_{i+1} of the same form by $A\Gamma_i = \Gamma_{i+1} R_{i+1}$ where R_{i+1} is upper triangular. If the Γ_i converge to a matrix Γ, then $A\Gamma = \Gamma R$, where the diagonal elements of R are the m eigenvalues of greatest modulus; and if y is an eigenvector of R, then $x = \Gamma y$ is an eigenvector of A.

The other method gives both row and column eigenvectors. Starting with matrices C_0 of m rows and B_0 with m columns, one forms, recursively, $C_i B_i = L_i R_i$, where L_i and R_i are lower and upper triangles respectively. Then form $B_i R_i^{-1} = \Psi_i$, $L_i C_i = \Phi_i$, $A\Psi_i = B_{i+1}$, $\Phi_i A = C_{i+1}$. If with any scalars α_i and β_i the matrices $\alpha_i \Psi_i$ and $\beta_i \Phi_i$ converge, and the limits are Φ and Ψ, then $\Phi A \Psi$ is diagonal with eigenvalues of A as elements, and the rows of Φ and the columns of Ψ are eigenvectors. Convergence in either case is assured, in particular when the eigenvalues are distinct in modulus. Other cases require special handling, which is discussed. A. S. Householder, USA

8. Yu, Y.-Y., On the generalized ber, bei, ker, and kei functions with application to plate problems, *Quart. J. Mech. appl. Math.* **10,** part 2, 254–256, May 1957.

Author points out that solution of $\nabla^4 y - s\,\nabla^2 y + ty = 0$ can be expressed in terms of the modified Bessel functions $I_0(z)$ and $K_0(z)$. Here $\nabla^2 = d^2/dx^2 + (1/x)d/dx$, and s and t are real constants. If $s = 0$, solution can be written in terms of ber, bei, etc., functions. If $s^2 - 4t$ is negative, pertinent functions are labeled as in title. Author comments that a problem discussed by Naghdi and Rowley [AMR **7,** Rev. 2434] is a special case of the present formulation, and states further that a series expansion for the solution given by the latter authors is rather complicated. The entire discussion is quite trivial, since the functions under consideration are the Bessel functions $J_n(z)$ and $Y_n(z)$, $n = 0, 1$ for complex z which are tabulated [AMR **3,** Rev. 2563].

Y. L. Luke, USA

9. Kestin, J., and Persen, L. N., On the error function of a complex argument, *ZAMP* **7,** 1, 33–40, 1956.

10. Hurwitz, H., Jr., and Zweifel, P. F., Numerical quadrature of Fourier transform integrals, *Math. Tables Aids Comput.* **10,** 55, 140–149, July 1956.

11. Bonfiglioli, L., A nomographic method of graphic integration, *Bull. Res. Counc. Israel* **6A,** 1, 1–10, Oct. 1956.

This method is based on the use of a special isosceles nomogram for the determination of areas bounded by graphs or geometric figures, or of definite integrals of functions given analytically, by representing each ordinate of a given curve $y = f(x)$ as the tangent of the angle between its respective ray and the x – axis.

The tangent values are marked on a nomographic scale of the function:

$$q\,y\,[2/(y+1)]^{1/2}$$

and the points thus obtained connected by rays to the origin of the nomogram. Integration is carried out by means of a strip of tracing paper with three parallel straight lines I, II, III drawn on it. The strip is moved over the nomogram and the segments cut off by the rays are added up graphically on line III. The conventional method of graphic integration is described, then the isosceles nomogram is explained, and its use for integration is illustrated by an example. Also the integration of an analytically given function is explained and illustrated.

K. J. DeJuhasz, Germany

Book—12. Churchman, C. W., Ackoff, R. L., and Arnoff, E. L., Introduction to operations research, New York, John Wiley & Sons, Inc., 1957, x + 645 pp. $12.

The first textbook in Operations Research succeeds admirably in fulfilling its objectives:

"1. To provide prospective consumers of Operations Research with a basis for evaluating the field and for understanding its potentialities and procedures.

"2. To provide *potential* practitioners with a survey of the field and a basis on which they can plan the further education required for competence with the methods and techniques."

The authors (and a large group of collaborators) present the techniques and the illustrative case histories at the level of college junior or senior. Therefore it is a primer rather than a handbook. The coverage is fairly broad and the case studies are well handled; it deserves a place on the book shelf, even if it is less of a milestone than the practitioner might desire. It is doubtful that a milestone volume covering the whole field will appear in the next five years.

There are a few errors which will no doubt be corrected in the next edition. Reviewer did not note any of major importance. It is rather unfortunate that the philosophic outlook of the authors, outlined so clearly in the first chapter, is not fully illustrated by an example of a study of a company or organization as a whole.

The chapters on inventory models deserve some special commendation. Several volumes on the subject, each of which purport to be the answer to the executive's prayer, have appeared. In this volume the inventory problem is treated in a clear and complete manner without beating the Wilson formula to death. The section on queue theory may appear overly brief, but it is as thorough as necessary to fulfill the quoted objectives.

This book is a good investment for management, engineers, and operations researchers, professionals as well as amateurs.

E. Koenigsberg, USA

13. Klein, M. L., Williams, F. K., and Morgan, H. C., Information theory, *Instrum. and Automat.* **29,** 8, 1519–1524, Aug. 1956.

14. Montague, K. E., Noble, M. D., and Buchanan, F. E., Application of engineering effort through use of reservoir analyzers, *J. Petr. Technol.* **8,** 12, 12–16, Dec. 1956.

Paper contains a review of the position which the reservoir engineer occupies in industry today. His work is found to be that of collecting, assembling, and analytically treating large quantities of basic data to the end that physical and economic results are optimized.

The need for methods to simplify and speed the data-collecting and analytical processes of reservoir engineering is discussed. An organization utilized by one company to speed these processes is described.

A general discussion of the use of analog computers and the result of six years' experience with this approach is given. It has been found that the reservoir engineer can quickly and easily adjust himself to the use of computers as a routine part of the solution to the over-all problem. In so doing, the burden of manual computation and data processing has been considerably lightened, thereby allowing him to devote more time to original and creative work in planning the basic approach and executing and applying economics to the end result.

From authors' summary

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 45, 67, 231, 250, 269)

15. Symposium on gear technology *ZVDI* **99,** 6, 213–266, Feb. 1957.

The February issue, 1957, of *VDI Zeitschrift* entitled "Getriebetechnik" comprises technical studies relating to different kinds of "Getriebe"; this term means, in technical German literature, mechanisms for which the motion of one member, the driving member, produces the motion of the other members. Two kinds of "Getriebe" are essentially considered: linked mechanisms and gears.

(a) Linked mechanisms. Dr. K. H. Sieker, V.D.I. Berlin, in "The four-bar mechanisms as a function instrument of high accuracy" shows how this mechanism can be so used that the angle ψ described by a member (the driven member) realizes a given function of the angle ϕ described by the driving member. Examples are produced for realizing a parabolic, a reciprocal, and an exponential function.

Ing. Kurt Hain, V.D.I. Braunschweig, examines in a first paper the mechanisms used for transmitting power from a hydraulically driven piston to an oscillating member. A simple construction gives the lever arm of the moment acting on this oscillating member and permits designing a mechanism answering to given conditions of force and moment. The use of tables and diagrams, some of which are produced in a second paper "Construction tables for

mechanisms," makes the synthesis of mechanisms easier. Prof. Rudolf Beyer, V.D.I. Munchen, author of the well-known "Technische Kinematic," considers in "Scientific means and methods for the investigation of space link mechanisms" the problem of the spherical link mechanism. The relations between the described angles, the velocities, accelerations, and the position of the momentary axes are established by geometrical methods combined with vectorial equations. The obtained results are in agreement with those published by the author in other papers where the matter is more generally treated. Dipl. Ing. R. Thiel, Braunschweig, considering that the real characteristics which occur in moving machine members differ greatly from the theoretical calculated ones, in "Measurement of dynamical behaviour in machines" exposes mechanical, and especially electrical, methods for measuring oscillations, velocities, accelerations, forces and moments, etc. An example, taken on an asymmetrical crank mechanism, shows the difference between the theoretical and the measured values. An ample bibliography is included.

(b) Gears. In a "Graphical method for calculating the coordinates of gears", Dr. Gustav Gerke, Esslingen/N, shows how the coordinates of intermediate shafts can be obtained with more accuracy than with trigonometrical calculation. The cases of one and two intermediate shafts are considered.

Von Obering. H. Hoffer, V.D.I. Friedrichshafen, in "Accurate undercutting calculations in gears", considers the case of a wheel of pitch radius equal to unity cut with a rack of 20° pressure angle and a top height u_1. A graphical method and a more accurate analytical one give, among other results, in function of u_1, the radius r where undercutting begins, taking into account an eventual correction displacement of the rack. The calculations are made for tools with sharp corners; an approximate method is given for rounded corners.

The paper "Dynamical forces in gears" of Dr. J. Zeman, V.D.I. Wien, contains a study of a mechanical device which he considers as equivalent to a gear system: two wheel masses pressed against each other by a constant force are separated by two springs whose distance f can be altered according to a periodic function of time (period T). It is shown that for the calculations two masses can be replaced by a single one. The cases where the change of f is caused by a single perturbation and that where f is caused by a continuous perturbation are considered. The influence of the ratio T/Te (Te: period of self oscillation) is shown through diagrams. The equations are applied to a system of two gears; the results are compared with the formulas of Buckingham Nieman and Tuplin, and discussed.

A paper from Egon Kamp, V.D.I. Huckeswagen, shows the possibility of lapping the gears, especially the bevel gears, in such a manner that the best running conditions should be realized.

The issue contains also a general survey on the improvements realized during the last years in the field of gears by Dr. H. Glaubitz, V.D.I. Wolfsburg; in the field of clutches and couplings by Dr. E. Martyrer, V.D.I., and J. Fromder, V.D.I. Hanover; and in the field of belts by Prof. K. H. Bossmann, Berlin-Dahlem.

D. De Meulemeester, Belgium

16. Lichtenheldt, W., Conference on gearing (in German), *Maschinenb.-Tech.* **5**, 11, 561-564, Nov. 1956.

Paper gives brief summaries of the following talks given in Conference held in Dresden on August 29, 1956: (1) Gear mounting; (2) Force transmission in gears with reference to tractor design; (3) Dynamic consideration in gear mounting; (4) Simple method for gear design; (5) Motion transmission in gear design; (6) Differential gears; (7) Gear tooth design; (8) Adjustable nonsymmetrical mechanisms; (9) Kinematics design in food production.

Summaries are brief and not informative.

W. J. Anderson, USA

17. Tolle, O., Velocity in multimembrane linkages. Application of the principles of virtual velocities with use of force polygons (in German), *Feinwerktech.* **58**, 7, 227-233, July 1954.

Author has found an elegant solution of the problem to find the velocities of all joints in a plain linkage when so much of the velocities of some joints is known that the motion is univocally determined. He introduces virtual forces into the joints where the velocities are known, and into one joint where the velocity is to be found. The forces are so chosen that they are in equilibrium. Then the unknown velocity can be found by the principle of virtual velocities. The method is elucidated by nine illustrative examples.

The reader may think the introduction of forces to be artificial. He may prefer the use of centros [see, f. i., Schwamb, Merril and James: "Elements of mechanism," London and New York, 1952, pp. 57-82; or by use of the Polesin L. Burmeister: "Lehrbuch der Kinematik," erster Band, Leipzig, 1888, p. 48-49] or virtual center [Alex, Kennedy: "The mechanisms of machinery," London 1886, 1907]. But Tolle recommends at least two different constructions for the sake of control, and the method, mentioned above, should be one of them. O. H. Faxen, Sweden

18. Katys, G.P., Investigation of the kinematics and dynamics of a three-dimensional rocking shaft mechanism (in Russian), Dvigateli vnutrennego sgoraniya, Moscow, Mashgiz, 1955, 240-250; *Ref. Zh. Mekh.* 1956, Rev. 5018.

Investigations of a rocking shaft mechanism having inclined cylinder axes; the crank shaft has an inclined neck on which a rocking shaft is fixed, connected with the aid of a telescopic joint with the gudgeon pin.

Graphical relationships of the path, velocity, and acceleration of the piston to the angle of rotation of the crank shaft are given.

The forces of inertia of the links and reaction in kinematic couples are determined. V. A. Zinov'ev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

19. Katys, G. P., Investigation of the kinematics and dynamics of three-dimensional crank mechanisms (in Russian), Dvigateli vnutrennego sgoraniya, Moscow, Mashgiz, 1955, 251-256; *Ref. Zh. Mekh.* 1956, Rev. 5019.

An investigation of a three-dimensional crank mechanism constructed on S.S. Shashkov's principle [*Bulletin of Inventions USSR* (1) Gostekhnika, 1946].

The single-cylinder mechanism consists of four mobile links; the axes of the shaft and of the piston are parallel to one another, the piston in the cylinder performs a screw movement. Diagrams of relationship of the path, velocity, and acceleration of the piston to the angle of rotation of the crank shaft are given.

The forces of inertia of the individual links and reactions in the kinematic couples are determined.

V. A. Zinov'ev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

20. Tarkhanov, K. S., Investigation of the general case of the universal joint mechanism (in Russian), Vopr. teorii mekhanizmov i mashin, Moscow, Mashgiz, 1955, 42-48; *Ref. Zh. Mekh.* 1956, Rev. 5033.

The mechanism of a universal joint is examined for the case when the output and input axes form arbitrary angles with the corresponding axes of the crosspiece, the axes of the crosspiece intersecting also at an arbitrary angle. With the aid of methods of descriptive geometry the relationship between the angles of rotation of the output and input forks is determined. By differentiation

with respect to time the relationship between the angular velocities of the output and input forks is determined.

M. I. Bat', USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

21. Manzheron, D. I., Graphical methods of analyzing the kinetics of material systems (in Russian), *Dokladi Akad.Nauk SSSR (N.S.)* **102,** 5, 897-898, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4960.

Formulation of certain equations on the distribution of accelerations of any order in the plane parallel motion of material systems. It is shown that from these equations a series of analogies and results is derived, which is of interest for the theory of mechanisms and graphical analysis in kinetics.

G. N. Duboshin, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

22. Katys, G. P., Three-dimensional mechanical transformer (in Russian), Dvigateli vnutrennego sgoraniya, Moscow, Mashgiz, 1955, 266-269; *Ref. Zh. Mekh.* 1956, Rev. 5027.

The mechanical transformer described is intended for conversion of the rotational movement of the shaft with an oblique crank into the screw movement of a piston sliding in a cylinder. In certain specific geometric parameters of the mechanism, rotation of the piston may be synchronized with the rotation of the shaft. It was shown that in the case of harmonic motion a four-cylinder in-line engine comes completely into equilibrium.

Author suggests making mechanisms of piston engines according to this arrangement.

V. A. Zinov'ev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

23. Fitch, C. J., Development of the electrostatic clutch, *IBM J. Res. Development* **1,** 1, 49-56, Jan. 1957.

A brief historical review of the electrostatic clutch operating on the Johnsen-Rahbek effect is presented. Mechanical design of a clutch, special lubrication, and the fabrication of electronically conductive clutch facing material are described. A high-speed, high torque-to-inertia ratio test model with bi-directional shaft control is described. With the clutch operating at 2500 rpm on 30 milliamperes at 150 volts, torques over 80 inch-pounds are available. The most useful single property of the electrostatic clutch is its fast response time. It can actuate levers, interposers, print hammers, optical gates, etc., in fractions of a millisecond; it can accelerate shafts to high rpm's with moderate loads in a few milliseconds from extremely low input control energy.

From author's summary

24. Sklyansky, A. L., The problem of conjugate impact in the generalized problem of three bodies (in Russian), *Ukr. mat. zb.* **7,** 2, 160-166, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4957.

Author examines the three-dimensional problem of three bodies mutually attracted with forces which are equal, according to the modulus $g^2 m_i m_j \exp(a/r_k)$, r_k being the mutual distance of the points m_i and m_j, and g^2 and a positive constants.

The motion of a system of three bodies close to double co-impact is investigated.

G. N. Duboshin, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

25. Cartaino, T. F., and Dreyfus, S. E., Application of dynamic programing to the airplane minimum time-to-climb problem, *Aero. Engng. Rev.* **16,** 6, 74-77, June 1957.

Authors conclude that dynamic programing offers a method of solution for the climb problem which is fast, is readily adaptable to routine engineering calculation, and allows the inclusion of the effects of variations in airplane weight and drag along the flight path.

From authors' summary

The following papers (Revs. 26-35) were from the Symposium on **Surveys in Mechanics, G. I. Taylor 70th Anniversary Volume,** New York, Cambridge University Press, 1956.

26. Hill, R., The mechanics of quasi-static plastic deformation in metals, pp. 7-31.

A survey of some of the work done in plasticity between 1949 and 1954. Paper first considers deformation of single crystals in simple shear, and goes on to consider general deformation of single crystals. The concept of the yield surface is developed for this case. It is shown that it must be convex and that the strain increment vector must be normal to it. The next section generalizes these results to crystalline aggregates and establishes the principle of maximum plastic work. There follow some experimental results favoring the Mises yield criterion. The plastic-rigid model is then considered together with its relationship to more realistic materials. The limit-analysis theorems which provide upper and lower bounds on the yield load are established.

Paper closes with a list of problem solutions using these theorems. It includes 83 references of which 65 are to work published since 1949.

P. G. Hodge, Jr., USA

27. Mott, N. F., Dislocations in crystal line solids, pp. 32-63.

Dislocations are crucially involved in most phenomena of plasticity, and in some of fracture of crystalline materials; but there is much uncertainty about how they produce the phenomena observed. There is no shortage in hypothetical dislocation mechanisms for various features of plasticity; it is mostly an open question, however, which—if any—of those so far suggested play a significant role in reality. Professor Mott's brief review indicates clearly the tentative nature of the majority of the hypotheses discussed today. After treating the nature and the energy of dislocations and dislocation-arrays, he describes the most prominent hypotheses about the origin of slip lines, of the yield stress, of strain hardening, recovery, creep, and related phenomena, with emphasis upon his own work, which, of course, it fully deserves.

There is one statement (representing the view of most theoreticians today) which the reviewer cannot follow: it is that the hardness of the face-centered metals and probably of most alloys of technical importance is determined solely by the interaction of dislocations with impurities and with other dislocations, and not by the stress needed for driving a dislocation forward in the absence of obstacles. If this were so, modern methods of chemical purification and crystal growth ought to permit the production, say, of an iridium that is as soft as lead, at least in the first stages of deformation.

E. Orowan, USA

28. Davies, R. M., Stress waves in solids, pp. 64-138.

Paper is a lucid survey of stress wave propagation in bounded media, based largely upon previous writings of the author [AMR **2,** Rev. 988] and of Kolsky [AMR **7,** Rev. 418]. Topics treated are: experimental techniques (production and measurement of stress waves), elastic waves in circular cylinders, viscoelastic waves in rods, and plastic waves in rods.

Section on experimental techniques is exceedingly well done, pointing out the various techniques available and their advantages and disadvantages. Discussion of elastic waves refers almost exclusively to the exact theory for solid circular cylinders; reviewer notes that the erroneous conclusion of Hudson concerning existence of only a single propagation mode for flexural waves is perpetuated. The sections on viscoelastic and plastic wave propagation are brief, but adequate for an introduction. Plastic flexural waves are not discussed and strain-rate effect is given only cur-

sory treatment. Reviewer feels that the existence of discrepancies between experiment and theory in the last two sections is not forcefully stated.

Reference list (105 entries) is excellent but does not extend beyond 1954. Paper is a must for newcomers to this important field and for all those who wish a brief survey of the topics covered.

H. N. Abramson, USA

29. Squire, H. B., Rotating fluids, pp. 139–161.

An account is given of the hydrodynamic aspects of rotating fluids. The chief interest derives from the novel features of the flow at large values of the angular velocity. For example, it was observed by Taylor that a sphere when moving up the axis of rotation pushed in front of it a cylinder of fluid in which the fluid had the same velocity as the sphere. In section one, a comprehensive review is given of the theoretical and experimental work between which there is a good measure of agreement.

In section three, the flows in which the swirl velocity is not large are considered. Here it is known experimentally that the flow past a body moving up the axis of rotation resembles that when the swirl is zero. However, in many cases the theoretical solutions are indeterminate. The most plausible extra condition, due to Long, to complete the solution is that the waves ahead of the body are damped out. Some of the implications have been worked out, but much remains to be done; notably to explain how the change-over occurs to a two-dimensional character at high angular velocities.

In section two, the motion due to a point source on the axis is discussed. As a result of the swirl, the fluid emanating from the source will remain on or near the axis, displacing rotating fluid, but its motion will be irrotational. In the displaced fluid, the angular velocity is a function of the distance r from the axis in the only possible steady motion. The author in fact assumes that it is constant, in disagreement with an earlier solution of Barua, who used the principles of conservation of mass and angular momentum and concluded that it was of the form

$$\Omega(1-a^2/r^2)$$

Reviewer believes that, while objections can be made to both solutions, Barua's solution is more plausible if the motion is steady.

K. Stewartson, England

30. Lane, W. R., and Green, H. L., The mechanics of drops and bubbles, pp. 162–215.

The mechanics of drops and bubbles are discussed, considering not only their dynamics but also the motion of fluid within and around them. The behavior of these systems presents problems not encountered in other branches of mechanics. By contrast to rigid spheres they may experience deformation, and then the two physical properties, surface tension and viscosity, exert a dominant influence. Internal circulation within the fluid of a drop or bubble may alter appreciably its dynamics and reaction with the surrounding medium.

The mechanics of drop formation is discussed first, and this is followed by an account of the motion of falling drops, their deformation and disruption. An important aspect is the deposition on obstacles of drops from a moving stream and the related problem of the collection of droplets in a cloud by a falling drop. The treatment is largely restricted to drops of macroscopic size formed in gas, leaving out of consideration such systems as mists, fogs and liquid aerosols in general, and fine liquid-liquid dispersions, commonly called emulsions.

Some chapter headings are: Shape of a pendant drop; Detachment of drops from tips; Production of drops: from tips, from spinning disk, and from swirl chamber; Behavior of falling drops: terminal velocity of spherical drop, swerving of drops, terminal velocity of large drops, empirical equations for terminal velocities, shape of falling drops, circulation in drops; Break-up of drops; Deposition of drops on obstacles from a moving stream; Collection efficiency of drops.

The section on bubbles deals with their formation, the dynamics of rising bubbles, and, finally, with the bursting of bubbles. With the exception of the last topic, the behavior of bubbles bounded by a liquid film (soap bubbles, foam, etc.) is not discussed. Bubbles can remain stable in sizes which are many orders of magnitude greater than the limiting size of drops. Chapter headings are: Production of bubbles: from orifices, from capillaries, "bubble rafts"; Behavior of rising bubbles: terminal velocity, vertical motion of large bubbles, large bubbles rising in tube.

K. J. DeJuhasz, USA

31. Ursell, F., Wave generation by wind, pp. 216–249.

32. Lighthill, M. J., Viscosity effects in sound waves of finite amplitude, pp. 250–351.

This article has as its subject "the conflicting influence on sound propagation of convection on the one hand, and of diffusion and relaxation on the other", whose importance in the determination of the structure of shock waves was first appreciated clearly by Sir Geoffrey Taylor. As an essential introduction to the main topics, author gives an exceptionally clear and valuable account of the physical mechanisms of viscosity, thermal conductivity, and other diffusion effects, including relaxation. The classical theory of shock-wave formation is then discussed, and some extensions are made.

The remainder of the article is based on the demonstration that the nonlinear equation for plane progressive sound waves, in which convection and diffusion are taken into account to a first approximation, can be transformed into Burgers's equation, the general solution of which was given by Hopf and Cole. This approach, in which all flows are continuous (they become discontinuous at shock waves in the limit as viscosity, etc., tend to zero), allows the author to re-derive and extend Whitham's theory of the formation and decay of weak plane shock waves, and to derive many new results, such as the velocity distributions during the union of two shock waves and during the formation of a shock wave. The application of the same idea to non-plane shock waves is also discussed, but more briefly; in these cases, Burgers's equation is not quite such a good approximation as before.

The article concludes with sections on sound waves whose Reynolds numbers based on the length scale of the flow and the velocity amplitude are comparable with unity, and on the effects of relaxation on the properties of shock waves. The whole is much more than a survey, and represents a very substantial advance in the theory of sound waves. It is the finest possible tribute to Sir Geoffrey Taylor that he should be able to inspire articles such as this and the others in this volume.

G. N. Ward, England

33. Batchelor, G. K., and Townsend, A. A., Turbulent diffusion, pp. 352–399.

Paper is a review of one-particle longitudinal diffusion in pipe, diffusion in decaying homogeneous turbulence, and lateral diffusion in immediate neighborhood of a source of contamination in shear flow. Results of analysis are compared with experiments. Two-particle diffusion and deformation of material lines and surfaces are also reviewed.

M. S. Uberoi, USA

34. Ellison, T. H., Atmospheric turbulence, pp. 400–430.

35. Davidson, K. S. M., The mechanics of sailing ships and yachts, pp. 431–475.

Servomechanisms, Governors, Gyroscopics

(See also Revs. 1, 2, 342)

36. Babister, A. W., Response functions of linear systems with constant coefficients having one degree of freedom, *Quart. J. Mech. appl. Math.* **10,** 3, 360–368, Aug. 1957.

Author considers using integrals in the square of the error and the square of the derivative of the error in a criterion for the optimum response of stable systems described by linear differential equations with constant coefficients. Expressions are obtained for these integrals in terms of the coefficients of the characteristic equation and the frequency response of the system. The relation between the response to different kinds of disturbances is treated. R. Oldenburger, USA

37. Kalman, R. E., Physical and mathematical mechanisms of instability in nonlinear automatic control system, *Trans. ASME* **79,** 3, 553–566, Apr. 1957.

This paper gives results of a fairly general—though of course not exhaustive—exploration of nonlinearity problems. Novel concept of "actual" and "virtual" critical points is developed; this is applicable to so-called "gain-controlling" nonlinearities, which include saturation, Coulomb friction, backlash, and feedback from continuous rotary devices (leading to "cylindrical phase spaces"). All these cases are treated, and some generalizations are arrived at about the characteristics of the types of systems in question. Actual and virtual critical-point concepts are used in conjunction with root locus method, leading to construction of phase-plane or phase-space diagrams, from which physical behavior of systems is deduced. Effect of input is analyzed, and author suggests that "many control systems with sufficiently strong nonlinearities may exhibit instabilities only when subjected to a small, special class of inputs."

Understanding of the paper requires some acquaintance with fundamentals of nonlinear system theory, and a fairly well-developed mathematical outlook. Although some interesting immediate results are brought out (for instance, light is shed on some limitations of the "describing function" technique), reviewer believes that chief value is as a contribution to our fundamental understanding of nonlinear systems, rather than as a tool for engineering problems.

R. Hadekel, England

38. Klotter, K., How to obtain describing functions for nonlinear feedback systems, *Trans. ASME* **79,** 3, 509–512, Apr. 1957.

A sinusoidal input to a nonlinear element will produce a periodic but nonsinusoidal output. The classical application of describing functions involves working with only the first harmonic of this nonsinusoidal signal. Author extends this procedure to include systems described by nonlinear differential equations (as contrasted with nonlinear relationships between input and output variables for nonlinear elements). Several examples of the procedure are given. V. B. Haas, Jr., USA

39. Stout, T. M., Basic methods for nonlinear control-system analysis, *Trans. ASME* **79,** 3, 497–508, Apr. 1957.

Author presents a summary of the methods presently employed for analysis and synthesis of nonlinear feedback control systems. The describing-function and phase-plane methods are emphasized. It is shown that the phase-plane is best adapted to the study of second-order systems and that the describing-function method is intended primarily for stability analysis of higher-order systems.

V. B. Haas, Jr., USA

40. Goldfarb, L. S., Method of investigating nonlinear systems of control based on the principle of harmonic balance (in Russian), Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. vol. 1. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 177–192; *Ref. Zh. Mekh.* 1956, Rev. 4997.

A method is explained for investigating systems of control which contain a nonlinear element and a linear portion which are described by differential equations of any order. Constructions are used which are similar to those of the frequency method of investigating linear systems; a harmonic character of oscillations is suggested.

The method is based on the principle of harmonic balance, which is a modification of the small parameter method.

Yu. A. Mitropol'skii, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

41. Petrov, V. V., Dynamics of one- and two-stage servomechanisms with several nonlinear characteristics (in Russian), Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. vol. 1. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 387–409; *Ref. Zh. Mekh.* 1956, Rev. 5000.

An attempt is made to systematize the results of investigations performed by the method of point transformations, and to supplement them so as to obtain a certain general view of the dynamic behavior of one- and two-stage servomechanisms with several nonlinear characteristics. Yu. I. Neimark, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

42. Pospelov, G. S., The vibration linearization of relay systems of automatic control. Reaction of relay systems to slowly varying disturbances (in Russian), Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. vol. 1. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 363–385; *Ref. Zh. Mekh.* 1956, Rev. 5001.

A short exposition of the theory of various methods of so-called vibration linearization of relay systems of automatic control.

The behavior of a system (self-oscillation, forced oscillation) with constant external action and the behavior of average variables of a system in the case of slowly changing external action are studied. Yu. I. Neimark, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

43. Moskvin, D. S., Matrix method of describing transitional processes (in Russian), Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. vol. 2. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 53–61; *Ref. Zh. Mekh.* 1956, Rev. 4990.

A method is described of calculating transitional processes in systems of automatic control, the equations of motion of which are written in the form

$$\frac{d}{dt}x(t) = Ax(t) + F(t)$$

in which A is a quadratic matrix with constant elements. The method is based on a formula of the form

$$x_{n+1} = Y_o x_n + \sum_{k=0}^{\infty} Y_{k+1} F_{n,k}$$

which relates the values of the column $x(t)$ at equal intervals. The calculation made according to this formula is arranged in a fairly convenient form and explained by an example. The possibility is shown of using the method for describing the construction of transitional processes in systems with distributed constants. V. A. Troitskii, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

44. Litvin-Sedoi, M. Z., Determination of static conditions of nonlinear systems of automatic control (in Russian), Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. vol. 2, Moscow-Leningrad Izd-vo Akad. Nauk SSSR, 1955, 523–530; *Ref. Zh. Mekh.* 1956, Rev. 4995.

45. Lange, A., Geometric stabilization, *J. aero. Sci.* **24,** 6, 465–466, June 1957.

The paper contains rederivations and additions to paper by Gorczycki [AMR **10,** Rev. 3739] concerning derivation of dynamic equations and servo instrumentation of intertial space-stabilized platforms. R. E. Kalman, USA

46. Mucha, E., Hydraulic actuators, *Prod. Engng.* **28,** 4, 175–177, Apr. 1957.

Formulas are given for a conventional hydraulic actuator and for simple geometry (the ram moves in a straight line) for these conditions: (1) zero inertia and zero external load; (2) zero inertia and constant external load; (3) inertia and constant or variable external loads.

The equations solve for velocity and piston travel, from which the time for full extension or retraction of the actuator can be calculated. Alternatively, required size of orifices at inlet and outlet may be determined for a reasonable piston speed and required time of operation. An actuator with internal damper is also considered. From author's summary

47. Reeves, E. L., Contributions to hydraulic control, Part 7, Analysis of the effects of nonlinearity in a valve-controlled hydraulic drive, *Trans. ASME* **79,** 2, 427–432, Feb. 1957.

Paper presents method for analyzing performance of control systems employing the well-known "four-way spool valve" as the basic controlling element. It applies to a specific positional control system in which the valve controls the flow to a piston type of linear servomotor used to position an inertia load. Problem treated is of considerable engineering significance because it is typical of many hydraulic control systems found in practice. Paper is of value because it considers the nonlinear nature of the valve's flow characteristics; this is conventionally neglected, but, nevertheless, has an important effect upon performance. This nonlinear effect is treated by the "describing function" method. Also considered in the analysis are load coulomb friction and compressibility of the oil in the piston chambers. These effects also are frequently neglected but prove to be significant.

A comparison is made between computed and experimentally observed results. Agreement is reasonable considering the difficulty of describing the complicated phenomena involved in mathematical form. Major disagreement is in the lower frequency region of the response. Discussor (M.S. Feder, Great Neck, N. Y.) suggests that this may be caused by striction (as opposed to the sliding friction already considered in the analysis). This discussor also points out that the important effect of force reactions on the valve stem were not considered in the analysis but admits difficulty in treating this effect and proposes it as a subject for further research.

Paper represents an important step toward the more complete understanding of a device of considerable practical interest but which, unfortunately, presents a large number of difficulties when subjected to analysis. R. Kochenburger, USA

48. Shearer, J. L., Use of nonlinear valve characteristics in the control of a simple blending process, *Trans. ASME* **79,** 2, 329–336, Feb. 1957.

Paper discusses dynamic behavior of a liquid-filled, well-stirred fixed-volume tank used to blend a hot flow of a given fluid with a cold flow of the same substance, so as to control the temperature of the effluent. Linear perturbation equations are derived for the dynamic behavior of the process when either the hot flow or cold flow is variable. A graphical analysis based on the slope-line method is used to check the analysis when the perturbations are large. The use of a valve with exponential flow versus stroke characteristics is analyzed and recommended for improved control under some circumstances.

R. E. Kalman, USA

49. Peters, E. H. J., A simplified method of mathematical treatment of a regulated distributable industrial process (in Dutch), *Tech. Wet. Tijdschr.* **26,** 1, 15–23, Jan. 1957.

To get an a priori grasp on the possibility of regulating many industrial processes, and the efficiency of a proposed regulating scheme, fruitful use can be made of logarithmic gain and phase diagrams, as known in the theory of servomechanisms. If levels, pressures, flows or temperatures are to be stabilized, most processes will be reducible by first approximation to concatenated capacities and resistances, the values of which can be determined by a simple proof. With the method of analysis and syntheses as applied in differential equations of higher order with real characteristics roots, a very satisfying way is found to obtain their precision and stability for every given value of the corrector.

From author's summary

50. Walther, L., Correct choice of automatic control devices (in German), *Regelungstech.* **3,** 12, 309–312, 1955.

Vibrations, Balancing

(See also Revs. 42, 64, 73, 74, 77, 191, 339)

51. Gillies, A. W., On a class of differential equation governing non-linear vibrations, *Quart. J. Mech. appl. Math.* **10,** 3, 342–359, Aug. 1957.

A differential equation of the form $f(D)x + g(D)y = F(t)$ is considered, with y a function of x, expansible in a series in powers of x; $F(t)$ is a simple periodic function, and D is the operator d/dt. The approximate linear equation when x and y are small is assumed to have one nearly sinusoidal normal mode, its other modes being exponentially damped with time constants less than a constant which is O(1). The solutions considered are of the form $2b\cos(\omega t+\phi)$ plus terms of higher order, when b and ϕ are either constants satisfying an amplitude equation or approximate to slowly varying functions of the time, satisfying an autonomous system of variational equations.

The variational equations are of four main types; in two of these the final state is a periodic solution or a combination oscillation determined by a singular point or limit cycle of the variational equations; in the other two the oscillation amplitude may increase until the variational equations cease to be valid, and the final state cannot be determined by the methods of this paper. From author's summary by L. Becker, USA

52. Thomson, W. T., and Barton, M. V., The response of mechanical systems to random excitation, *J. appl. Mech.* **24,** 2, 248–251, June 1957.

Authors conclude as follows: "A statistical treatment for any linear structure excited by random forces has been presented in a general manner, such that knowing the normal vibration modes of the structure and the power spectral density of the excitation, the mean square response can be evaluated. The probability of the response is then available under an assumption of normal distribution. ....."

Two examples, one dealing with longitudinal motion of slender rods and another with lateral motion of beams, are given to illustrate the statistical approach.

L. S. Dzung, Switzerland

53. Noll, W., Displacement function for elastic vibration problem (in German), *ZAMM* **37**, 3/4, 81–87, Mar./Apr. 1957.

To quote from the author's abstract: "in this paper both the displacement potential of Galerkin-Westergaard and Love's function are generalized in such a manner that they can be used not only for static problems but also for vibration problems of linear elasticity...." The generalized equations have the advantage of explicitly showing both the longitudinal (dilatation) and transverse (shear) modes of vibration.

In the development of the generalized potential, the difference in the character between the longitudinal and transverse vibrations is clearly shown. Noll's result which shows that Love's function exists only for those problems in which the curl of the displacement field is parallel to an arbitrary fixed plane is compatible with the known behavior of these two types of vibrations.

Reviewer believes that these results will prove most useful in the integral formulation in the transient three-dimensional stress problems. An example of this application is the calculation of the transient stresses in a breech block.

E. E. Covert, USA

54. Gillies, A. W., The periodic solutions of the differential equation of a resistance-capacitance oscillator, *Quart. J. Mech. appl. Math.* **10**, 1, 101–121, Feb. 1957.

55. Etkin, B., On a third mode of longitudinal control-fixed oscillation, *J. aero. Sci.* **24**, 1, 71–73 (Readers' Forum), Jan. 1957.

56. Goldsmith, W., and Cunningham, D. M., Kinematic phenomena observed during the oblique impact of a sphere on a beam, *J. appl. Mech.* **23**, 4, 612–616, Dec. 1956.

Experimental investigation is made of beam deflection, time of contact, and crater configuration with oblique impact for different initial velocities and beam sizes. Deflection varies with normal velocity component. Contact duration is predicted by Hertz theory. Depth and width-to-length ratios of craters decrease with increase of beam flexibility. The first evidence of disturbance travels at about halfway between dilational wave velocity and rod wave velocity. The pulse of maximum strain has a velocity halfway between that for rod waves and Rayleigh surface waves. Reference is made to earlier papers on instrumentation and bending stresses.

E. G. Fischer, USA

57. Babaev, N. N., Transverse vibrations of bars of varying cross sections accounting for shearing deformation and for internal inelastic resisting forces (in Russian), *Inzbener. Sbornik, Akad. Nauk SSSR* **22**, 17–25, 1955.

Problem of vibrating bar with hysteresis is attacked by breaking the rods into segments connected alternately by two types of joint. One of these is a hinge with a damper and spring resisting bending; the other is a slider with a damper and spring opposing transverse displacements. Mass is concentrated at the hinge points. An equation for the frequency of free vibration, in closed form, culminates the derivation. Aside from the fact that definitions for symbols must be ferreted out here and there in the text, the results should prove useful for direct application.

It should be pointed out that the result is not intended to apply to the rotating shaft with hysteresis.

R. A. Burton, USA

58. Soroka, W. W., How to predict performance of rubber vibration isolators, *Prod. Engng.* **28**, 7, 141–145, July 1957.

A method for predicting the performance of viscoelastic materials is presented. To simulate creep behavior of such materials (rubber, nylon, etc.), a relaxation unit, consisting of a dashpot in series with a spring, is introduced. With this relaxation unit parallel to a spring, the performance of a viscoelastic vibration isolator can be predicted more precisely than with the conventional method, using only a dashpot parallel to the spring. Especially the behavior under the action of a shock gives more reliable results.

Graphs showing the ratio of transmissibility, dynamic stiffness, and damping loss with and without a relaxation unit are presented.

H. Bergh, Holland

59. Hagel, W. C., and Clark, J. W., The specific damping energy of fixed-fixed beam specimens, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-18, 5 pp.

The internal damping effects of varying composition, heat treatment, cold work, magnetic-field strength, stress history, and static tension stress have been studied at room temperature using fixed-fixed beam specimens supported in a new bending vibration-decay apparatus. Experimental logarithmic decrements are converted to specific damping energies by a straightforward numerical method; such information is needed to extend a fundamental understanding of the physical nature of damping and to provide useful engineering design data. Changing hardness from 225 to 388 Bhn was found to cause a wider variation in AISI 403 specimen damping than the application of a static tension stress or d-c magnetic field. Even at relatively low vibration stresses, considerable energy dissipation originates from microscopic plastic flow in soft materials.

From author's summary by R. K. Bernhard, USA

60. Eringen, A. C., Response of beams and plates to random loads, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-5, 7 pp.

Restricting himself to classical damped-plate equation and time-independent boundary conditions, author solves for the Fourier transform of transverse displacement in terms of the eigenfunctions and eigenvalues, and shows that the power spectrum function is the Fourier transform of the corresponding cross correlation function. Under assumptions (1) orthogonality of eigenfunctions and (2) pressure cross correlation function proportional to Dirac delta function, author completes solution for cross correlation functions of displacement, stresses and moments, and states usual expression for expected value. Examples are given for beams and plates under different edge conditions.

C. N. DeSilva, USA

61. McGoldrick, R. T., Buoyancy effect on natural frequency of vertical modes of hull vibration, *J. Ship Res.* **1**, 2, p. 47, July 1957.

Effect of buoyancy of surrounding eater on ship hull vibration is taken account by means of a restoring force per unit length per unit transverse displacement and found to be less than 1% for most ocean-going ships.

J. Hult, Sweden

62. Wigle, B. M., and Jasper, N. H., Determination of influence coefficients as applied to calculation of critical whirling speeds of propeller-shaft systems, *David W. Taylor Mod. Basin Rep.* 1050, 15 pp., May 1957.

Reports from the same source [AMR **9**, Revs. 663, 1374] give formulas for calculating critical speeds of propeller shafts. These call for "influence coefficients"—static responses of the propeller to unit forces and torques. This report shows a method of calculating these influence coefficients from measurements taken directly from the shaft, propeller, and the supporting bearings.

R. E. Gaskell, USA

63. Tacho, J., Calculation of the critical speed of a rotor by numerical integration (in French), *Bull. tech. Suisse Rom.* **83**, 6, 81–86, Mar. 1957.

Author gives numerical method to calculate influence coefficients of shaft on several supports. He uses these in standard

fashion [Timoshenko, "Vibration problems," section 47] to find characteristic equation for finite number of masses.

R. Plunkett, USA

64. Holzweissig, F., The method of "distributed inertias," and the effect of shaft inertia, in torsional frequency calculations (in German), *Maschinenbau-Technik* **6**, 2, 72-75, Feb. 1957.

Method is explained and derived in which multiple discrete rotors (on uniform shaft) are replaced by a single hyperbolically distributed ("smeared out") rotor inertia. For case of equal rotors, torsional natural frequencies are compared with classical solution, considering effect of shaft inertia. Unfortunately, no comparisons are given for a case of large rotor size range (on a single shaft), for which accuracy of this technique seems to be more critical.

G. A. Nothmann, USA

65. Javorsky, P., and Klier, E., The study of torsional vibration of EDT (Russian with English summary), *Czech. J. Phys.* **4**, 3, 316-334, Sept. 1954.

66. Vosteen, L. F., McWithey, R. R., and Thomson, R. G., Effect of transient heating on vibration frequencies of some simple wing structures, *NACA TN* 4054, 10 pp., June 1957.

The influence of thermal stresses on the stiffness of simple wing structures was established experimentally, by measuring changes in natural frequencies of vibrations due to radiant heating.

It has been found that the temperature gradients approaching those required for thermal buckling and the temperature distributions in chordwise direction have the greatest effect on the wing stiffness.

The wing models tested had the following cross sections: a rectangular, a double wedge, and a circular arc multi-web wing section.

W. Ornstein, USA

67. Smiley, R. F., Some considerations of hysteresis effects on tire motion and wheel shimmy, *NACA TN* 4001, 45 pp., June 1957.

Author's previous analysis of shimmy problems [AMR **9**, Rev. 3855] suggested tire hysteresis might be important, and gave a very simplified treatment. Present paper examines effect of hysteresis on forces and couples exerted by tire on ground when motion is (1) long wave length with sideways displacement, (2) angular displacement only. Results of this analysis may be incorporated in shimmy theory. Good agreement between theory and experiment has been obtained in this way.

D. J. Johnson, England

68. Fitswilliams, D. L. L., Vibration problems associated with the helicopter, *J. Helicopt. Assn.* **11**, 3, 110-155, June 1957.

69. Coleman, R. P., and Feingold, A. M., Theory of self-excited mechanical oscillations of helicopter rotors with hinged blades, *NACA TN* 3844, 131 pp., Feb. 1957.

This note combines the following NACA publications, which are reissued with appropriate corrections:

1. NACA Advance Restricted Report 3G2g, 1943 (Wartime Report L-30S), entitled, "Theory of self-excited mechanical oscillations of hinged rotor blades," by Robert P. Coleman.

2. NACA Advance Restricted Report 3I13, 1943 (Wartime Report L-312), entitled, "Theory of mechanical oscillations of rotors with two hinged blades," by Arnold M. Feingold.

3. NACA Technical Note 118y, 1947, entitled, "Theory of ground vibrations of a two-blade helicopter rotor on anisotropic flexible supports," by Robert P. Coleman and Arnold M. Feingold [AMR **1**, Rev. 543].

J. F. Besseling, USA

70. Biggs, J. M., Suer, H. S., and Louw, J. M., The vibration of simple span highway bridges, *Proc. Amer. Soc. civ. Engrs.* **83**, ST 2 (*J. Struct. Div.*), Pap. 1186, 33 pp., Mar. 1957.

Paper describes theoretical analysis and model and full-scale field tests of "vibratory" response for two-lane, through-span, steel-concrete highway bridges of girder and stringer types. Bridge is idealized to simple damped oscillator characterized by half-sine first mode. Loading consists of uniformly moving damped oscillator producing two-component, impulsive-type loading: first, half-sine pulse at "span-crossing" frequency of moving vehicle dead weight; second, half-sine modulated periodic load at "carrier" frequency of sprung vehicle inertia effect. Problem is not one of "resonance" but of shock loading (transient). First component loading consequently is not important here because of large pulse-responder period ratio. It could be more critical at high speeds. There might be question if sum and difference of vehicle and span-crossing frequencies play a role. For higher crossing speeds, sum could be effective.

Principal results in Fig. 17 consist of "positive side" of non-dimensional shock displacement-response envelope as function of ratio: "oscillatory" vehicle impulse period over responder period. Analysis is based on pair of coupled linear differential equations with periodic coefficients representing bridge and load motion. Solutions are effected on automatic analog and digital computers.

Both model and field test seem well verified by calculations. Some interest could attach to seeing test points plotted on Fig. 17.

Several practical conclusions are presented for design application, emphasizing response most pronounced near coincidence of vehicle springing and bridge "natural" (first mode) frequencies. For establishment of definitive specifications, a series of Fig. 17-type shock-response envelopes for significant parameterizations appear valuable.

P. R. Hardesty, USA

71. Fuhrke, H., Mass reduction used in approximative determination of natural frequencies of multimass systems (in German), *Stahlbau* **23**, 8, 181-184, Aug. 1954.

Wave Motion in Solids, Impact

(See also Revs. 24, 28, 53, 56, 75, 78, 184)

72. Robinson, A., Transient stresses in beams of variable characteristics, *Quart. J. Mech. appl. Math.* **10**, 2, 148-159, May 1957.

Jones [AMR **9**, Rev. 1022], considering the case of a beam of constant characteristics, has shown that for a disturbance which is produced by a concentrated impulse, the bending moment is discontinuous even across the fronts of the shear waves. In the present paper, this phenomenon is studied for a beam of variable characteristics, and the law of variation of the discontinuity is determined.

From author's summary by H. N. Abramson, USA

73. Ruhl, K., and Pagel, H. J., Recent investigations of the strains produced in beams by lateral impact loading (in German), *Forsch. Geb. Ing.-Wes.* **22**, 6, 202-209, 1956.

Authors present results of an extensive set of measurements of bending and shearing strains produced by lateral impact on beams. Beams included in study were simply supported railroad rails and cantilevers with rectangular sections. Results are presented in tables and curves. Authors have also investigated bending-strain propagation past a splice in an I-beam, and the effects of interposing cushions of lead and rubber between the impacting mass and the beam. The splice was found to have an observable though small effect. As might be expected, the cushions reduced bending strain by an appreciable factor. Some comparisons of measured

values with predicted values are shown, but the paper is primarily a presentation of experimental results. As such, it should be useful to anyone interested in developing or checking approximation formulas for shear and bending stresses in beams subjected to lateral impacts. E. A. Ripperger, USA

74. Zachmanoglou, E. C., and Volterra, E., A second approximation of the method of internal constraints as applied to dynamic problems, *Rensselaer Polytech. Inst. Tech. Rep.* 6, 38 pp., May 1957.

This paper is a continuation of a series by the senior author [AMR **9,** Revs. 1700, 1727] in which he extends a method which he devised originally for the solutions of statical problems in elasticity to dynamical ones. The method is an approximate method and, initially, assumptions are made concerning the internal elastic displacements; they are assumed to be restricted in certain prescribed ways (hence the term "internal constraints"). In the first instance, the values of the strains consistent with the assumed displacements are calculated, then the kinetic and potential energies, and finally, by applying Hamilton's principle, the partial differential equations of the motion are derived. Hitherto, the method has been used to give a first-order correction to the elementary theories; for example, in the familiar case of the propagation of extensional waves in a straight circular cylinder, the radial displacement u_r was assumed to be directly proportional to the radial distance r from the axis.

In the present paper, the method is extended to include second-order terms; in the case of the circular cylinder, u_r is now taken to be the sum of two terms, the first proportional to r and the second to r^3. The unknown functions involved in the second-order terms are determined in terms of the unknown functions in the first-order terms, using the condition that the normal stresses on the free surfaces vanish identically. The equations of motion and the boundary conditions for free and fixed ends, etc., are again derived by applying Hamilton's principle.

The authors first derive the equations of motion for flexural and longitudinal waves in bars of rectangular and circular cross section and for solids which fulfill the conditions for plane stress and plane strain. They next proceed to investigate the dispersion of waves of these types propagated in bodies which are infinite in extent in the direction of propagation. Finally, they discuss free, flexural vibrations of straight bars of finite length, subject to various combinations of end conditions.

The test of any approximate theory of this nature is to compare its results with those given by an exact theory. Two comparisons are available: a comparison of the dispersion curves and a comparison of the magnitude of the field vectors and their variations over the cross section. The authors have carried out the first check and their results show a decided improvement on the first-order approximation; for many purposes, the final accuracy will be adequate. The second check has not been made; in fairness, it should be added that, although this comparison is more important than the first in some respects, nearly every author of every recent paper on approximate theories of wave propagation has committed this error of omission. R. M. Davies, Wales

75. Kumar, S., and Davids, N., Multiple scabbing in materials, *J. Franklin Inst.* **263,** 4, 295–302, Apr. 1957.

Paper discusses first scabbing and multiple scabbing from a phenomenological point of view, then past experiments on scabbing with critical comments. It next suggests new types of experiments and the use of an inverse approach which could yield information on pulse shapes and some of the dynamic properties of the material. The relationships among these quantities have been determined graphically. From authors' summary

76. Tocher, D., Anisotropy in rocks under simple compression, *Trans. Amer. geophys. Un.* **38,** 1, 89–94, Feb. 1957.

Compressional velocities through samples of several types of rocks have been measured while the samples were subjected to simple compression in a hydraulic press. Velocity measurements were made in directions parallel to and perpendicular to the direction of the compression, with the amount of compression varying from zero up to the rupture point. All measurements were made at room temperature and with no confining pressure other than that of the atmosphere.

Velocities in a direction parallel to the compression increased with compression in a manner somewhat similar to the increase found by other workers in samples subjected to hydrostatic pressures. Velocities in a direction perpendicular to the compression also increased, but at a much lower rate. The differences in the two velocities amounted to over 10% in some cases.

The differences in velocities are large enough to suggest the possibility of making a rough determination of the state of strain in the neighborhood of a recognized active fault which is known or suspected to be near vertical. Possible applications toward the prediction of rock-bursts are also suggested.

From author's summary

77. Ghosh, M., and Ray, K., Dynamics of the vibration of a bar excited by transverse impact of an elastic load. II, *Indian J. theor. Phys.* **3,** 4, 151–160, Dec. 1955.

This paper deals with dynamics of vibration of the bar fixed at one end struck transversely by an elastic hammer at the free end. The bar is assumed to behave as a loaded bar so long as the hammer is in contact with it and the elastic hammer is conceived of as a perfectly hard hammer backed by a weightless spring. The expressions for the displacement at struck point, pressure exerted by the load during impact, have been worked out. The case of a hard hammer has been deduced as a special case by putting the elastic constant of the hammer equal to infinity. The results obtained in part I [AMR **10,** Rev. 1718] come also as special cases.

From authors' summary by T. H. H. Pian, USA

78. Breklovskikh, L. M., and Ivanov, I. D., A special form of damping during wave propagation in lamellar inhomogeneous media (in Russian), *Akust. Zh.* **1,** 1, 23–30, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5070.

An examination was made of wave propagation in a layer which is bounded on one side by a nonhomogeneous medium in which the wave propagation velocity decreases with the distance from the boundary of the layer. The second boundary of the layer is assumed to be absolutely reflecting. It was shown that wave propagation in this layer is accompanied by an additional weakening, which is caused by a "sucking away" of the wave energy by a nonhomogeneous medium. The value of the additional damping was determined in relation to the distance from the radiator, the wave length, the disposition depth of the receiver and of the radiator, and the value characterizing the variation in the velocity of sound according to the depth in a nonhomogeneous medium.

Courtesy Referativnyi Zhurnal Yu. P. Lysanov, USSR
Translation, courtesy Ministry of Supply, England

Elasticity Theory

(See also Revs. 53, 59, 66, 72, 74, 76, 98, 102, 103, 108, 112, 117, 139, 143, 285)

79. Ling, C. B., Stresses in a perforated strip, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-8, 11 pp.

Author presents an analytical solution of two-dimensional stresses in an infinite strip of finite width within which an eccen-

tric circular hole is located. The solution, consisting of four biharmonic series and a biharmonic integral, is more general than existing solutions in the following aspects: the hole is eccentric, hence the solution includes the symmetric hole as a particular case; also, stresses at any point in the strip may be described by the present solution.

The solution appears tedious, involving successive approximation at one point, but it is considered by the reviewer as an important contribution. Two simple numerical examples of simple tension and transverse bending are worked out.

D. H. Cheng, USA

80. Brown, E. H., The diffusion of load from a stiffener into an infinite elastic sheet, *Proc. roy. Soc. Lond. (A)* **239,** 1218, 296–310, Mar. 1957.

Using complex variable theory author develops a new technique, reducing certain problems with mixed boundary conditions to second-order functional differential equations.

Exact solutions are given to three fundamental problems of the diffusion of load in an infinite two-dimensional elastic sheet to which a semi-infinite elastic stiffener is continuously attached throughout its length. The first problem has a load applied to the end of the stiffener, with its line of action along the stiffener and its reactions at infinity. In the other two problems the stiffener end is unloaded but a uniform tension is applied to the sheet at infinity, in one case parallel to the stiffener, in the other perpendicular to it. Expressions for the load in the stiffener and for the direct and shear stresses in the sheet are found and plotted in nondimensional form.

From author's summary by V. Bogunovic, Yugoslavia

81. Argyris, J. H., Matrix theory of statics (in German), *Ing.-Arch.* **25,** 3, 174–192, 1957.

Author gives a comprehensive discussion of stress and strain calculations in elastic trusses. The matrix formulation is orderly and convenient for machine computation. The change in stress distribution due to a change in stiffness of some elements of a given truss is obtained without recomputation of the whole distribution.

C. M. Ablow, USA

82. Atsumi, A., On the stresses in a strip under tension and containing two equal circular holes placed longitudinally, *J. appl. Mech.* **23,** 4, 555–562, Dec. 1956.

Author uses a perturbation method to solve the plane stress elasticity equations with the radius of the hole and the distance between the holes as parameters. Numerical examples show that the stress concentration factor as compared to that for a single hole of the same geometry is smaller when the holes are close together. If the diameter of the holes is small compared to the width of the strip, the edges appear to have no effect on the stresses.

B. E. Gatewood, USA

83. Chakravorty, J. G., On the distribution of stress in a hollow aeolotropic cylinder by a localised shear on a boundary, *Bull. Calcutta math. Soc.* **48,** 4, 171–176, Dec. 1956.

Author treats the problem of determining the stress distribution in a cylindrically anisotropic medium. The boundary-value problem is solved in a cylindrical coordinate system. The case of a cylindrically isotropic medium results as a specialization. This problem has been treated in general by Soviet elasticians and can be found in Lechmtski's text "Theory of anisotropic solids" (1950), in Russian.

J. J. Brandstatter, USA

84. Chakravorty, J. G., On the distribution of stress in an infinite circular cylinder of transversely isotropic material caused by a band of uniform pressure on the boundary, *Bull. Calcutta math. Soc.* **48,** 4, 163–169, Dec. 1956.

Author gives an exact solution to the title problem by means of the Fourier integral. An approximate solution to an analagous problem was given by Westergaard in 1941. Trauter in 1946 and Elliot in 1948 have also treated similar problems. Reviewer suggests that the author scan the work of the Soviet workers in this field so as to avoid duplication of publication.

J. J. Brandstatter, USA

85. di Mauro Pacelli, N., Compression and torsion of elastic bodies in contact (in Italian), *Atti Accad. naz. Lincei R. C. Sci. Fis. Mat. Nat.* (8) **21,** 5, 296–303, Nov. 1956.

Paper presents the static problem of the contact with friction of two generic bodies pressed together and then twisted around their common normal. Assuming that the normal stresses in the area of contact are those given by Hertz' theory, it is necessary to find the distribution of the shearing stresses. Author uses the previous results of J. L. Lubkin, "The torsion of elastic spheres in contact," *J. appl. Mech. (Trans. ASME)* Sept. 1949, and C. Cattaneo, "Sulla torsiones di due sfere elastiche a contatto," *Ann. Scu. norm. sup. Pisa* (III) **6,** 1952, and "Compressione e torsione nel contatto tra corpi elastici di forma qualunque," *Ann. Scu. norm. sup. Pisa* (III), **9,** 1955, based upon the same assumptions. Lubkin gave an exact solution in the case of two spheres, Cattaneo in 1952, using the same hypothesis but employing a different analytic procedure, found in the case of two spheres a solution expanded in a series, and in 1955 he generalized the solution for two generic bodies. Between Cattaneo's solutions for two spheres and two generic bodies there is a formal analogy which is for the same order, independent of the order of the approximation used. Author, employing an inductive procedure suggested by the previously stated analogy, builds the general solution (two generic bodies) from Lubkin's exact solution for two spheres. The procedure is checked by verifying that the results obtained fit the integrodifferential equation corresponding to the problem in question.

C. A. Sciammarella, Argentina

86. Swida, W., Pressure on the inside of prestressed concrete (in German), *Bauingenieur* **31,** 2, 52–55, Feb. 1956.

The state of stress in areas perpendicular to a prestressing element is considered for pretensioned prestressed concrete and in prestressed concrete with thin wires. Here the longitudinal tensile stresses diminish, when the connection is solved between the steel and the stressing device. By the resulting contraction of area in steel arise tangential tensile stresses and radial compressive stresses in concrete. Author explains formulas for calculation of the stresses in regard to triaxial tensions in steel. The longitudinal stresses in concrete are at first neglected, but in a second method their consideration is included. Author also explores radial and tangential stresses in concrete at the ends of the wires, where the tensile force of steel is introduced in concrete.

A calculated example shows that the tangential tensile stresses in concrete have smaller values when we consider the longitudinal compressive stresses in concrete as well. The calculated tensile stresses are so great that we must suppose the concrete will tear. The fact of no tearing in many finished examples can be explained by the very small space in which these stresses work, for they reduce with the distance from the middle of the prestressing element according to a hyperbolic rule.

G. Brandes, Germany

87. Filin, A. P., A direct method for solving boundary-value problems (in Russian), *Inzbener. Sbornik, Akad. Nauk SSSR* **22,** 53–64, 1955.

Linear differential equations with two or three coordinates as independent variables are solved in the form of a sum of two series, each series progressing in orthogonal functions. One of the series is supposed to solve the inhomogeneous differential equation; the other series satisfies inhomogeneous boundary conditions. Either the first series satisfies homogeneous boundary conditions term by term, or the second series satisfies the homo-

geneous differential equation term by term. The method is applied to the bending of plates and to other problems of elasticity.

This is a fine piece of applied mathematics following the work of Bubnov, Galerkin, Trefftz, and Brillouin.

R. Eisenschitz, England

88. Mar, J. W., and Schmit, L. A., Some structural penalties associated with thermal flight, *Trans. ASME* **79,** 5, 990–1004, July 1957.

Authors determined the thermal stresses to be anticipated in the multicelled wing of a supersonically maneuvering aircraft. Two questions are posed by the authors:

1. What types of flight missions will impose the most severe aerodynamic heating effects on the structure?
2. How are these effects to be superimposed with the familiar maneuvering loads?

A very interesting analysis is made to determine the temperature distribution, and resulting stresses, during various maneuvers. A digital computer program (Whirlwind I) was used in solving the finite difference formulation of the temperature and stress problem, although no details are given regarding the calculations.

The authors then, in answering the second question, evaluate the weight penalty caused by considering the effects of thermal stresses in addition to the usual flight loads. The stress criterion is that "The combination of maneuver stress and thermal stress is not to exceed the allowable stress."

The weight penalty is calculated assuming that a certain portion of the structural integrity has been "used up" by thermal stress and that only the remainder is available for resisting maneuvering loads. A comparison of "thermal stress weight penalties" using an aluminum alloy, titanium alloy, and Inconel X is then made.

Reviewer takes some exception regarding the assumptions of "allowable thermal stresses." This feeling is based on the inherent difference between stresses resulting from thermal and those resulting from mechanical loadings. In the case of thermal loading the stresses arise from a condition of self-restraint and tend to relieve themselves by yielding of the material. Because of this, unusually large elastically computed stresses (well beyond the yield point of the material) can be sustained by the material without failure. The art of determining the design allowable thermal stress is still in its infancy although a great deal of fine work has been done by L. F. Coffin, Jr. [AMR **9,** Rev. 2925] and others.

If we tentatively allowed the sum of mechanical and thermal stresses to be twice the yield stress (although still retaining the usual criteria for stresses due to normal flight loads), the thermal stresses calculated by the authors would appear to result in no weight penalty.

A. L. Ross, USA

89. Brooks, W. A., Jr., Griffith, G. E., and Strass, H. K., Two factors influencing temperature distributions and thermal stresses in structures, *NACA TN* 4052, 13 pp., June 1957.

Effect of thermal conductivity of joints is shown to increase thermal stresses in airplane structures. Normal fabrication procedure may give joints of poor conductivity and authors describe case where, of six supposedly similar multiweb wings, one had considerably higher thermal stresses due to poorer joint conductivity. Internal radiation will, on the other hand, reduce thermal stress. Preliminary experimental results confirmed this statement, but reduction was less than indicated by idealized theory.

F. I. Niordson, Sweden

90. Heaps, N. S., Transient thermal stress in a flat plate due to non-uniform heat transfer across one surface, *Aero. Res. Counc. Lond. curr. Pap.* 299, 22 pp. + 6 figs., 1956.

A long rectangular plate at uniform temperature, free of external restraints, suddenly exposed to a higher temperature over one surface is considered. On the exposed surface a heat-transfer coefficient which varies inversely as the square of the distance from one of the longitudinal edges is postulated. Thermal and mechanical aspects of problem are treated one-dimensionally, temperature differences through the thickness of the plate being neglected and resulting stress distribution found by elementary methods. Numerical results are presented and discussed with reference to the aerodynamic heating of the wings of an aircraft when suddenly accelerated to a high supersonic speed.

J. H. Weiner, USA

91. Roy, S. K., On the biharmonic analysis of thermal stresses around openings in structures, Proceedings of the First Congress on Theoretical and Applied Mechanics, Nov. 1–2, 1955, pp. 125–140; Kharagpur, Indian Inst. of Technology. $6.

Author develops method of solving elastic generalized plane stress problems in the presence of temperature gradients and finds an explicit solution for a radially symmetric case. This latter solution gives the stresses about a circular hole in a plate, subject to a radial temperature gradient with radiation from the plane surfaces.

D. R. Bland, England

Experimental Stress Analysis

92. Sutton, G. W., A photoelastic study of strain waves caused by cavitation, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-15, 9 pp.

In spite of the destructive effects of cavitation on marine propellers, the microscopic size of the phenomenon and its rapid transient nature have hindered its full understanding. A method of producing acoustic waves in water on a small scale was used to produce cavitation at the surface of a $\frac{1}{16} \times \frac{1}{16} \times \frac{1}{4}$-in. CR-39 specimen in the laboratory. Photoelastic effects were observed over an area 0.004 in. square just inside the surface of the plastic with a multiplier phototube and oscilloscope. The records indicate a periodic strain variation in the plastic due to the pressure variations and a sharp peak at the part of the cycle where the pressure becomes positive. The duration of this peak, which gives rise to a strain wave, is about 2 microsec. High-speed photographs were taken of the photoelastic pattern, and these also show the formation and disappearance of the bubble cloud. A disturbance of the pattern can be seen to be associated with the disappearance of the bubbles.

More than half the paper is devoted to a careful investigation of the mechanical and photoelastic properties of CR-39, both static and dynamic. Author concludes that in this material the birefringence is proportional to strain, not stress, an interesting result in itself. The dynamic modulus of elasticity was measured from the free-free vibrations of bars of various lengths and was found to increase rapidly with frequency. The dynamic fringe value was determined under impact loading in which the strain was applied in about 25 microsec. Extrapolating these quantities to the frequencies set up in the test, the calculated stresses due to cavitation are about 2×10^5 psi.

A. F. C. Brown, England

93. Kuske, A., Frozen-stress techniques: three-dimensional photoelastic stress analysis, *Engineering* **183,** 4751, 397–402, Mar. 1957.

94. Mittelmann, G., Strain gauge measurement of steel stress in P. C. constructions, *Civ. Engng. Lond.* **52,** 608, 167–170, Feb. 1957.

95. Cole, D. M., Jr., and Ralls, J. A., The Northrop load maintainer and load proportioner system, *Proc. Soc. exp. Stress Anal.* **14,** 2, 37–54, 1957.

Paper describes a load maintainer utilizing a servo valve to control the load exerted by a hydraulic cylinder. This valve is

mounted in a half-ring dynamometer which is fastened to the load attachment point in series with the strut. Deflections of the dynamometer, due to changes in load, cause the servo valve to displace and readjust the strut pressure. Load levels may be preset and altered remotely. With the addition of the load proportioner, a system of loads of various amounts may be controlled as a single group. This load proportioner constitutes a central control station where all loads are automatically set, applied, monitored, adjusted, and recorded under the direction of one operator. Detailed descriptions are given of the apparatus, and examples are presented of applications in the field of structural testing, for both static and repeated loads.

From authors' summary

96. Brouns, R. C., and Baird, R. B., Aircraft structural testing techniques at elevated temperatures, *Trans. ASME* **79,** 5, 1005–1013, July 1957.

The object of this paper is to review some of the test-system requirements and problems associated with structural testing of aircraft at elevated temperatures. A brief description of loading methods used for the past generation of aircraft is presented. The requirements of an elevated-temperature test facility are established on the basis of the need for simultaneous heating and loading of an aircraft structure. Heating devices such as heating blankets, strip heaters, film heaters, induction coils, radiant heating coils, and infrared lamps which are being investigated by the Wright Air Development Center are discussed in relation to methods of attaching loads. Complications caused by simultaneous heating and loading are illustrated by a discussion of two structural tests performed at the Wright Air Development Center. A description is also given of an electronic computer developed to program the aerodynamic heating of a structure.

From authors' summary

97. Kotanchik, J. N., Experimental research on aircraft structures at elevated temperatures, *Proc. Soc. exp. Stress Anal.* **14,** 2, 67–80, 1957.

The equipment and methods used at the Langley Laboratory of the NACA in experimental research on aircraft structures at elevated temperatures are reviewed. The equipment ranges from conventional steady-state furnaces for stress-strain tests to transient radiant-heating apparatus and aerodynamic heating and loading in a supersonic air jet. From author's summary

98. Suzuki, M., Determination of the distribution of maximum shearing stress on metal surfaces by means of electroplating method, Proc. 6th Japan nat. Congr. appl. Mech. 103–106, Mar. 1957.

Paper is concerned with the stress distribution in a twisted shaft containing a comparatively large transverse hole. The relation between the critical value of shearing stress which forms flecks and the number of cycles of stress has been obtained for the first time. The distribution of the maximum shearing stress is determined both at the edge of the hole and within the bore by observing the area having a color change which is produced at various numbers of cycles of a prescribed twisting moment.

The stress-concentration factor obtained in this manner agrees well with the result of earlier authors [AMR **8,** Rev. 3347].

H. Okubo, Japan

Rods, Beams, Cables, Machine Elements

(See Revs. 15, 16, 19, 46, 52, 56, 57, 60, 63, 70, 72, 77, 105, 107, 123, 139)

Plates, Disks, Shells, Membranes

(See also Revs. 8, 60, 87, 91, 109, 110, 111)

99. Georgian, J. C., Uniformly loaded circular plates with a central hole and both edges supported, *J. appl. Mech.* **24,** 2, 306–310, June 1957.

Author solves title problem using classical plate equations for conditions: (a) clamped at both inner and outer edge, and (b) simply supported at inner and outer edge.

Significant moments and deflections are plotted graphically against the ratio of inner radius over outer radius of the plate. Results may apply to diaphragms (case a) and plate valves in compressors (case b). R. E. Beckett, USA

100. Mader, F. W., Contribution to the computation of plate strips (in German), *Ing.-Arch.* **25,** 3, 201–204, 1957.

Author presents method of analysis of simply supported plate strips under arbitrary loading conditions. The fundamental solution, in terms of which others are formed, is that of the simply supported plate strip loaded along one of its edges by an arbitrarily varying moment. The result is expressed in terms of a Fourier integral. By the process of superposition, author solves problems such as the plate strip loaded along a line segment parallel to its edges, a clamped plate strip, and a two-section plate strip, supported at its outer edges and along a line midway between these edges. The method is a simple extension of similar processes used for beams and plates of finite width. The main disadvantage of the use of the theory is that the definite integrals which arise are difficult to compute. H. J. Plass, Jr., USA

101. Kholmianskii, M. M., Transverse bending of elastic thin plates in the form of a circular sector (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **22,** 199–205, 1955.

In his book on the theory of plates, B. G. Galerkin indicated a scheme for obtaining influence functions for sectorial plates, simply supported along the rectilinear edges. These functions were given in the form of infinite series, while in the present paper they are given in closed form, using a different approach to the problem. In addition, the problem is also solved for clamped rectilinear edges. G. Herrmann, USA

102. Struble, R. A., Biezeno pressure vessel heads, *J. appl. Mech.* **23,** 4, 642–645, Dec. 1956.

Author calculates expressions for shape, volume, and surface area of a thin-walled pressure vessel of constant maximum shearing stress—a "Biezeno head." He then compares the shape of an "ideal Biezeno head" (one having maximum shearing stress equal to that in a cylinder to which it is joined) with those of ellipsoidal and optimum torispherical heads, and concludes that they are very similar. H. D. Conway, USA

103. Burmistrov, E. F., Calculations of dome-shaped orthotropic shells with consideration of finite deformations (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **22,** 83–97, 1955.

Author considers shells with positive main curvatures which may be assumed constant all over. Projection of shell onto horizontal plane is rectangle of side-ratio c. Loading is normal. Two cases of boundary conditions are studied: (a) edges simply supported but restrained in the horizontal direction, (b) edges simply supported and free in horizontal direction. Edges are parallel to planes of elastic symmetry. Problem is to solve for two fourth-order differential equations involving both $w(x,y)$ and $\phi(x,y)$, stress function.

For (a), $w(x,y)$ is postulated as a double series with terms $A_{mn}\cos\alpha_m x \cdot \cos\beta_n y$. Each term of the differential equations is written as a series of similar type. By repeated integration and

rearrangement of series, the corresponding $\phi(x,y)$ is found. Relations between coefficients of the various series are indicated. A first approximation with $w(x,y)$ having one term is worked out. Results are tabulated for two orthotropic and two isotropic media, with $c = 1$, or 2, under uniform normal load. Listed are the ratio rise/thickness for which the shell may buckle (snap) and corresponding critical load.

For (b), w and ϕ are postulated as double series with terms involving circular and hyperbolic functions. A procedure for solving, based on variational principle, is indicated. A first approximation with w and ϕ having one term each is worked out. Results are shown in tabular form for the same media. The ratio rise/thickness and corresponding critical load are given.

Extension is indicated to case of linearly varying load. Results for isotropic shells and plates can be deduced from study.

G. H. Beguin, USA

104. Vorovich, I. I., On certain direct methods used in the nonlinear theory of sloping shells (in Russian), *Dokladi Akad. Nauk SSSR (N.S)* **105,** 1, 42–45, Nov. 1955.

Buckling Problems

(See also Rev. 103)

105. Barta, J., On the stability of the equilibrium of a compression bar of variable cross section (in German), *Acta Techn. Hung. Budapest* **17,** 3/4, 306–310, 1957.

A lower and an upper bound are deduced for the critical value of the compressive force by means of the usual theory of buckling. It is supposed that both ends of the bar are hinged. The method is similar to the bounding procedure of Schwarz known from the literature.

From author's summary

106. Bolcskei, E., The limit-load carrying capacity of compression bars made of perfectly plastic materials, *Acta. Techn. Hung. Budapest* **17,** 3–23, 1957.

The paper concerns the load-carrying capacity of a beam-column of rectangular cross section that is subjected to an eccentric compressive load. The longitudinal fibers are assumed to behave in an elastic, perfectly plastic manner and fail when the strain reaches a critical absolute value. The beam-column is considered to have reached its load-carrying capacity when the critical strain is attained in a surface fiber of some cross section.

W. Prager, USA

107. Sattler, K., Considerations on snap through of reinforced concrete beams (in German), *Bautechnik* **33,** 11, 378–383, Nov. 1956.

108. Zender, G. W., and Pride, R. A., The combinations of thermal and load stresses for the onset of permanent buckling in plates, *NACA TN* 4053, 10 pp., June 1957.

A simple and practical method is outlined for evaluating the onset of permanent buckling in plates in the presence of combined thermal and compressive load stresses. The results indicate that the compressive load stress which the plate can support at the onset of permanent buckling is substantially reduced as the temperature difference of the plate and adjoining members increases.

From authors' summary by F. I. Niordson, Sweden

109. Thurston, G. A., Bending and buckling of clamped sandwich plates, *J. aero. Sci.* **24,** 6, 407–412, June 1957.

Analysis is made of clamped rectangular sandwich plates subjected to lateral loads as well as uniform in-plane compression in one direction. Principle of minimum potential energy is used in conjunction with Fourier series and the Lagrangian multiplier method. Author uses Hoff's energy expression, including stretching energy of face plates, bending energy of face plates, and shear-strain energy of core. Determinants providing upper and lower bounds to the compressive buckling load are obtained, and numerical results are calculated, for various core stiffnesses, over a range of plate aspect ratios. The calculation was evidently made for the case of vanishing face-plate bending stiffness, but author quotes calculations indicating that, in practice, neglecting face-plate bending leads to negligible error. The numerical results were obtained from the upper bound solution, but author's spot check by means of lower bound solution indicate excellent accuracy. Author claims good agreement of calculations with experimental results obtained by Forest Products Laboratory.

B. Budiansky, USA

110. Klein, B., Buckling of simply-supported rhombic plates under externally applied shear, *J. roy. aero. Soc.* **61,** 557, 357–358, May 1957.

Paper is actually a brief note on the title subject. The method of collocation is used to derive buckling loads. Results are presented in the form of a curve for the aspect ratio b/a between 0.5 and 1.5. The notation and symbols are incompletely defined so that reviewer was unable to check the case of a square plate, that is a equals b, against the result in Timoshenko's book on the theory of elastic stability. In fact there appeared to be a discrepancy of a hundred per cent in the buckling load, which no reasonable assumption concerning the definitions could remove.

W. H. Hoppmann II, USA

111. Chwalla, E., and Steiner, H., On the buckling of pressurized shaft casings (in German), *Öst. Bauzeitschr.* **12,** 3, 57–67, Mar. 1957.

Tunnels and vertical shaft linings, as well as underground storage tanks, may be subjected to external pressure from several sources. Among these are ground water, creep and shrinkage of the concrete outer shell, and temperature changes. The peculiar element of the problem, as distinguished from other shell buckling problems, is that outward radial displacements are restrained by the mass of the surrounding earth or rock.

Authors consider circular shells and solve the eigenvalue problem by energy methods, considering two limiting cases: buckling of a free tube, and buckling of a tube restrained by a rigid envelope. A case in which the tube contacts the wall of the envelope on one side only is also investigated. Results for the limiting cases are compared in numerical examples. Thermal buckling is treated as a variation of the basic problem.

A. D. Topping, USA

112. Zuk, W., Thermal buckling of clamped cylindrical shells, *J. aero. Sci.* **24,** 5, p. 389, May 1957.

Joints and Joining Methods

(See Rev. 128)

Structures

(See also Revs. 52, 62, 70, 81, 86, 89, 96, 114, 131, 132, 239, 309, 340, 341)

113. Anonymous, Two unusual timber structures, *Timber Technol.* **65,** 2218, 403–405, Aug. 1957.

A 115-ft square roof, consisting of four 57-ft 5-in. square hyperbolic paraboloid shells and supported only at the four mid points of each roof side, was designed and built in England with three

layers of tongued and grooved ⅝ × 5-in. European redwood boards fastened to each other with more than 100,000 nails of 1¼-in. length.

Eight trapezoidal stressed-skin plywood "crystal spires" of 72-ft height, inclined and fastened to each other, form the 111-ft long, 37-ft wide, and 70-ft high British Government Pavilion for the 1958 Brussels Exhibition.

These two new structural timber designs are outstanding from the engineering viewpoint, since they take full advantage of the properties of the wood and plywood used.

E. G. Stern, USA

114. Rudnicki, J. M., Wooden containers and pallets, *Timber Technol.* **65,** 2218, 411–414, Aug. 1957.

Means and methods are discussed and analyzed for better and more economic use of wood in the manufacture of containers and pallets.

Tests indicate that, for instance, butter boxes with double-nailed rebated vertical edges can be replaced to advantage by stronger and more economical single-nailed "engineered" boxes if properly threaded nails are used.

In testing pallets, concentrated loads were applied over an area slightly smaller than 5% of the pallet deck area, according to the author the most dangerous type of loading.

E. G. Stern, USA

115. Basic facts about fir plywood diaphragms, Douglas Fir Plywood Association, Tacoma, Wash., Form No. 57–220, 8½ × 11 in., 10 pp., Aug. 1957.

The well-illustrated folder provides complete technical and design data on plywood diaphragms, their application and construction. It is a valuable aid to engineers and architects confronted with the design of diaphragms.

All data are based on the use of common wire nails, although special threaded nails with extra large shank diameters and considerably smaller shank length, which reduce the construction cost of diaphragms, are manufactured for this and similar purposes.

E. G. Stern, USA

116. Heebink, B. G., Dimensional stability of glass-cloth-reinforced laminates, *U.S. Dept. Agric., For. Prod. Lab. Rep.* no. 1858, 5 pp. + 8 tables + 2 figs. July 1956.

Over-all changes in dimension of approximately 0.070 and 0.110% were determined for laminates made of 181 glass cloth with a typical polyester resin and a typical high-temperature-resistant resin, respectively, when they were exposed to a change in relative humidity of from zero to 100%. The amount of change in dimension was increased slightly by an increase in resin content. The average thermal coefficients of expansion were approximately 8.5×10^{-6} and 3.4×10^{-6} per degree Fahrenheit for the regular polyester and the high-temperature-resistant resin laminates, respectively, in the range of 0 to 180F.

From author's summary

117. Konishi, I., and Komatsu, S., Three-dimensional stress analysis of a box-girder bridge (in Japanese), *Trans. Japan Soc. civ. Engng.* **43,** 1–10, Feb. 1957.

This paper proposes a method of analysis, based on the bending torsion theory, for the determination of the stress distribution in both main box girder and floor beam of the two-box-girder bridge, which is subjected to the torque loading. During the loading, the greater the width, the more its cross section deforms generally; in other words, it can be considered that each box girder individually induces some local twist besides the torsion, as one body, of a whole cross section, because of their large torsional rigidity.

In order to clarify the influence of such local twist on the stress flow, the warping function of the second kind is availably introduced, and then classical analysis is appropriately modified so as to be useful for our problem.

Numerical example on one actual composite box-girder bridge, under contemplation in Japan, shows that this deformation of the cross section changes somewhat the effect of the load-distributing action of the floor system.

Referring to the lower cover plate in the center cross section of one box girder under the torsion, difference of the normal stress value at the middle point from one at the side was about 10%.

Finally, a brief analysis of the statically equivalent structure is developed. Its approximate solutions are quite good for practical design purpose in comparison with above exact analysis.

Thus, using this solution, the distribution rate of the loads, concerning the bending moment at the middle section of main girder, is calculated and plotted corresponding to various stiffness ratios between main girder and floor beam.

S. Okamoto, Japan

118. Wicka, B., Exact determination of the maximum deflection of a vierendeel beam of parallel chords by the joint-rotation method (in German), *Bautech.-Arch.* **33,** 4, 131–133, Apr. 1956.

Author applies method of joint rotations (Drehwinkelverfahren) to determine the maximum deflection of a vierendeel beam, symmetrical and with parallel chords. For this purpose he writes joint displacements in terms of joint rotations (Takabeya) and solves the resulting system of linear equations. The value obtained for deflection is compared with the values obtained with the virtual work theorem.

A. J. Bignoli, Argentina

119. Odman, S. T. A., Energy methods of statics applied to linear boundary-value problems, *Sven. Forskningsinst. Cement Betong Medd.* 30, 19 pp., 1954.

Mathematical concepts used in solving boundary-value problems are described and illustrated by reference to examples. The relations between methods based on the principles of minimum of error potential and minimum of potential energy, on the principles of virtual forces and virtual displacements, and on the theorem of Castigliano and the law of conservation of energy are demonstrated. This paper would probably interest only the theoretical worker.

R. B. B. Moorman, USA

120. Martin, A. R., The role of statistical methods in controlling the quality of non-ferrous castings, *J. Inst. Metals* **85,** 209–226, 1956–1957.

Paper aims at bridging the gap between foundry practice and the standard textbooks on statistical methods of process control. Those methods suitable to foundry purposes are discussed, and a consideration of conventional ways of treating and presenting test data is used to lead up to worked examples showing how the appropriate statistical approach is selected and the results which may be expected from its application.

From author's summary

121. Wright, W., The design of skew slabs, *Concr. constr. Engng.* **52,** 3, 113–114, Mar. 1957.

122. Green, N. B., Design of floating slab foundation, *J. Amer. Concr. Inst.* **28,** 9, 889–898, Mar. 1957.

123. Mees, L. A. A., Bending moments at the supports of continuous beams, *Concr. constr. Engng.* **51,** 9, 483–490, Sept. 1956.

124. Petrasovits, G., Methods of tunnel design and their evaluation (in Hungarian), *Mélyépitéstudományi Szemle* **6,** 7/8, 321–327, July/Aug. 1956.

125. Fentzloff, H. E., Systematic scheme of hydro-power utilization (in German), *VDI-Forschungsheft* **22,** 453, 48 pp., 1956.

The technique of hydraulic power utilization shows at present a remarkable great variety of power station types as the result of the possibilities to combine the three constructional elements: concrete construction, machinery, and steel construction. A fundamental and systematic scheme was developed covering the whole range from high pressure over medium and low pressure of river regulation to the utilization of tidal waters and including all types of plant, their constructional elements, their economical character, their limits of applicability, and also the course of their development from the past to the future. The basis of this system is the rule, now arrived at, of the contrast between river and tidal water utilization as the consequence of the opposite causes of water movement in rivers and in sea bays. Dimensionless considerations based on relative terms of the water rates, the pressure heads, the utilization times, the power, and the work resulted in establishing the field of relative power in which the general planning of each river system from its origin to its mouth may be represented in a uniform manner for judging the design, morphology and power output conditions. Similarly, a field of relative work enables the designer to derive the fundamental rules for the economy of river and tidal utilization.

From author's summary

126. Bohmer, J. F., The exact curvature of pretensioning cable (in Danish), *Tekn. Skr.* no. 14 N, 11 pp., 1956.

Author deals with the problem of determining the exact curvature of the pretensioning cable which, owing to uniform distributed load, will give momentless stress distribution throughout the beam.

This curvature is, in the literature, supposed to be the circle as well as the parabola of the second order. Obviously, the exact curve cannot be either of these, even if the difference cannot be great. Because of the constant S-force in this cable, it would have to be raised a little compared with the parabola. On the other hand, the vertical component of S must not exceed the share force in the section, so the curve is strictly limited.

The differential equations are established assuming no friction at the pretensioning, and solutions are found by successive approximations.

By taking friction into account, additional correction terms are found. The corrections are small, 5—10% each. It can be concluded that this must be the case even for more complicated constructions, e.g., continuous beams.

Further, the moments are very small when the vertical component of S is of the same magnitude as the share in the section.

Practically, the theoretical curve is not of great importance because usually both change of load intensity and distribution occur, thus giving moments.

By proper selection, however, of the two variables, the magnitude of the pretensioning force and its eccentricity, any two extreme moments can be taken by a section with stresses chosen.

Stress concentrations may be taken by additional nonprestressed reinforcement. From author's summary

127. Flexible culverts under high fills, *Nat. Res. Counc. Highway Res. Bd. Bull.* 125, 9 papers, Jan. 1955.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 26, 27, 58, 59, 106, 136, 137, 230)

128. Shield, R. T., The application of limit analysis to the determination of the strength of butt joints, *Quart. appl. Math.* **15,** 2, 139–147, July 1957.

The technique of limit analysis is applied to determine upper and lower bounds for the tensile strength of a butt joint consisting of a thin layer of adhesive joining the parallel flats of two rigid adherends. The adhesive is assumed to be an elastic-perfectly plastic material which yields when the maximum shear stress reaches a critical value. The methods used apply to any joint with a convex area of cross section. Particular application is made to joints whose cross sections are circular, rectangular, or a polygon circumscribed about a circle.

From author's summary by G. Winter, USA

129. Takizawa, E. T., Rheological theory of anisotropic media, *Mem. Fac. Engng. Univ. Nagoya* **8,** 1, 118–126, May 1956.

Author presents the mathematical theory in a tensorial and more generalized form of anisotropic viscoelastic bodies of the liquid-like and solid-like types. The equations of state are linear and take into account thermal effects. For simplicity, author further introduces the Maxwellian relaxations into the equations of state. Energy expressions and formulas for heat in flow and change of temperature are then derived, followed by a discussion on the formal applicability of the theory to various problems.

Paper, on the whole, is presented in a very condensed form, and a preacquaintance with the subject, including author's previous work, is necessary. Z. Karni, Israel

130. Bhatnagar, P. L., and Lakshmana Rao, S. K., Problems on the motion of non-Newtonian viscous liquids, Proc. Indian Acad. Sci. (A) **45,** 3, 161–171, Mar. 1957.

Making use of Reiner's stress-rate of deformation relation

$$t^i_j = F_0\,\delta^i_j + F_1\,d^i_j + F_2\,d^i_\alpha\,d^\alpha_j$$

authors derive the more general form of Navier-Stokes equation and apply them to problems of incompressible viscous liquids. F_1, F_2 are assumed constant.

It is shown that for a plane motion in a conservative field of force the vorticity and circulation are independent of the cross-coefficient, hence the study of some plane problems follows the classical treatment. L. Rintel, Israel

Failure, Mechanics of Solid State

(See also Revs. 26, 27)

Book—131. Freudenthal, A. M., editor, Fatigue in aircraft structures (Proceedings of the International Conference, Columbia University, New York, Jan. 30, 31, and Feb. 1, 1956); New York, Academic Press Inc., 1956, xiii + 456 pp. $12.

As the result of longer operational life and increasingly severe service conditions, fatigue in aircraft structures has become an increasingly critical problem which was emphasized in recent years by the accidents to the British Comet airliners. This book is a compilation of 19 separate papers presented at an International Conference on Fatigue in Flight structures in 1956 to discuss the present state of the art. The papers are arranged in three principal groups: (I) the first five on physical theories of fatigue, (II) the next six on prediction of fatigue life and fatigue strength of structures with a complex stress history, and (III) the final eight papers dealing with the practical aspects of design and development for the prevention of fatigue failure in structural members. The authors include many recognized leaders in the fields of fatigue and aircraft design from England, Sweden, France, Australia, Scotland, Germany, and the United States.

The papers of part I offer theory and some experimental data on the basic mechanisms of fatigue damage in metals. Discussions cover phases of crack initiation, crack propagation, some related effects such as mechanical hysteresis losses, and the influence of variables such as temperature and range of cyclic stress on the fatigue mechanism. Much of the evidence is based upon microexamination of slip and cracking in the early stages, but forms the basis for hypotheses relating to the initiation of cracking by move-

ment by dislocations, concentrations of thermal energy, etc.

The papers of part II discuss the effectiveness of a fatigue crack as a stress raiser and its response to cyclic loading; it is shown that under certain conditions some cracks can be "non-propagating." Most of the contributions of part II are aimed at: (a) appraising the cumulative damage arising in a *material* from a random variation (or for a particular type of variation) in load history, (b) evaluating the types of load spectra to be expected under typical operating conditions for various types of aircraft, and (c) discussing methods of predicting fatigue life of a structural component on the basis of known load spectra and basic material characteristics that were obtained from *constant* stress amplitude tests. These problems require careful consideration of the statistical nature of both loading and material properties and a reevaluation of the significance of laboratory test methods as related to full-sized aircraft structural members.

The latter part of the text contributes more specific design methods that have been attempted in predicting life for a given load spectrum and the dependence of a "fail-safe" design on: (a) rates of crack propagation, (b) remaining static strength, and (c) the attention given to modification of design details of specific components to prolong their fatigue life. Many excellent examples are shown of the effectiveness of minor changes in details of hole patterns fillet-radii, and fabrication methods that can be utilized to improve fatigue life.

In general the book summarizes in a concise manner the current practices utilized in the aircraft field for preliminary estimates of fatigue life in major structural components such as wings, and gives a good summary of some of the basic concepts of initial fatigue damage. Since it is slanted strongly to the airplane field it does not attempt to summarize the entire knowledge in the field of fatigue but is strongly biased in the area of appraising damage from load histories peculiar to aircraft wings. It should prove of great value to aircraft designers by acquainting them with the major problems involved, and by calling to their attention the seriousness of the problems of progressive fracture that arise in modern aircraft structures. T. J. Dolan, USA

Material Test Techniques

(See also Rev. 96)

132. Leeman, E. R., and Grobbelaar, C., A compressometer for obtaining stress-strain curves of rock specimens up to fracture, *J. Sci. Instrum.* **34,** 7, 279–280, July 1957.

133. Wright, P. J. F., Compression testing machines for concrete, *Engineer* **203,** 5283, 639–641, Apr. 1957.

A study has been made of the discrepancies sometimes observed when nominally similar concrete cubes are tested on two or more different machines. A major cause of these discrepancies was found in misalignment of the components of the testing machine. Other important factors are the planeness of the platens of the machine and the maintaining of a constant rate of loading right up to the failure of the specimen. The freedom of movement of self-aligning platens has also been found to affect the results; a platen which adapts itself initially to the shape of the specimen and thereafter does not move gives less variable results than a platen which remains free to move under high loads. These points are embodied in a set of recommendations for the use of concrete compression testing machines. From author's summary

134. Roth, W., Non-destructive testing by ultrasound; objectives and potentialities, *J. acoust. Soc. Amer.* **29,** 1, 2–4, Jan. 1957.

Ultrasonic propagation is affected by elastic properties of material, distribution of material, and stress continuity. Since these are properties that determine structural strength of manufactured parts, ultrasound is useful for nondestructive testing. Variations in internal properties of structure can be detected, but it is often not possible to evaluate the effect that detected structural variations have on the ability of a part to function properly. This paper takes a critical view of the nondestructive testing field in the light of this objective. From author's summary

135. Kopineck, H-J., and Hoff, H., Testing of thin metal sheets with ultrasound (in German), *Stahl u. Eisen* **77,** 11, 727–734, May 1957.

136. Stauffer, W., and Keller, A., Special features of creep tests (in German), *Schweiz. Arch.* **22,** 12, 389–402, Dec. 1956.

The character of the creep curve obtained by long-time creep tests and rupture tests may be different and may sometimes vary in a considerable way from the classical form of the curve. Both kinds of plotting of the curves, i.e., the linear and the double logarithmic one, have their advantages and disadvantages. Even the lines of the creep rupture strength and the creep limit depending on time in the double logarithmic system of coordinates differ from each other as to character and design. The embrittlement determined by stress rupture tests must not necessarily be similar to that obtained on notched impact test bars.

From authors' summary

137. Boettner, R. C., and Robertson, W. D., Constant stress creep apparatus, *Rev. sci. Instrum.* **27,** 12, 1039–1040, Dec. 1956.

A simple creep apparatus for approximating a constant stress in tensile specimens of large cross sections, where large applied loads are required, is described. The apparatus consists of a lever with a large built-in mechanical advantage, together with means for removal of incremental weights from the applied load.

From authors' summary

138. MacDonald, R. J., Carlson, R. L., and Lankford, W. T., An apparatus for the determination of stress-strain properties at high rates of strain, *Proc. Soc. exp. Stress Anal.* **14,** 1, 163–170, 1956.

Paper describes an equipment used for high-speed tensile testing of sheet steel. Low-carbon sheet steel used in commercial deep-drawing procedures has to be tested at deformation speeds giving strain rates from 0.5 sec^{-1} to 1.0 sec^{-1}. Such strain rates can not be obtained with conventional test machines. Described apparatus, which is a combination of a high-speed hydraulic press and a specially designed jig, covers a strain-rate range from 0.001 to 0.8 sec^{-1}, the bottom values identical with those of conventional machines and top value approaching rates of impact testing.

Equipment is adapted to testing under various temperature conditions by a special, insulated tank, temperature range from −100 F to 400 F being covered. Load measurement is executed by a wire strain-gage dynamometer bar combined with an analyzer and oscillograph. Maximum test load is 2000 pounds, and the reading accuracy of the recording device is approximately 5 pounds. Strain measurement is obtained by an extensometer, a semicircular clip-gage equipped with wire strain gages connected to a recording device, enabling strains to be distinguished within a total range of 0.275 inch per inch with a reproducibility of 0.001 inch per inch. Some examples of the use of equipment are illustrated, such as variations in yielding behavior affected by strain rates and different test temperatures for a low-carbon, rimmed, annealed, deep-drawing steel. Effects from increased strain rates upon yield-point values are discussed. R. Nilson, Sweden

Mechanical Properties of Specific Materials

(See Revs. 58, 59, 113, 115, 116, 120, 131, 138, 144, 143, 170, 276, 282, 302, 309)

Plasticity, Forming and Cutting

(See also Revs. 26, 138, 143, 282)

Book—139. Donaldson, C., and LeCain, G. H., Tool design, second edition, New York, McGraw-Hill Book Company, Inc., vii + 577 pp. $6.75.

This is an enlarged and up-to-date version of the original (1943) edition. It is clearly written with a large number of good problems and presents the various subjects pertaining to tool design in a logical manner. The book is practical in nature and sticks closely to its avowed purpose of training the student to write specifications for modern manufacturing methods. Principal prerequisites for its study are an elementary knowledge of machine tools, engineering drawing, and strength of materials. The use of strength-of-materials fundamentals although not extensive is considerably greater than that in many books in tool design.

The general topics discussed are tool drafting, manufacturing processes, properties of materials, tolerances and allowances, springs, welding, cutting tools, punch and die design, gages and gage design, jigs and fixtures, automatic screw machines, cams and turret lathe tooling. The sections on welding, cutting tools, punch and die design, and cam design have been considerably increased since the first edition.

Most serious omissions, in reviewer's opinion, are three important and somewhat related topics: grinding, surface finish, and cutting fluids. These receive very brief mention, although they would appear to deserve detailed treatment in such a text.

The book can certainly be recommended for private or class study and would be a useful addition to the personal library of many practicing mechanical engineers.

I. Finnie, USA

140. Johnson, W., The plane strain extrusion of short slugs, *J. Mech. Phys. Solids* **5,** 3, 202-214, 1957.

Modifications to steady-state slip-line field solutions for the region in which these fields would lie outside the work material are suggested. Both smooth and rough chamber walls are considered. The extrusion pressure is plotted as a function of the length/thickness ratio of the slugs. A qualitative rationalization of piping is given which the reviewer cannot follow.

J. F. W. Bishop, Scotland

141. Johnson, W., Partial sideways extrusion from a smooth container, *J. Mech. Phys. Solids* **5,** 3, 193-201, 1957.

The extrusion of sheet through a square die inclined at an angle of 60° to the chamber wall is discussed. The reduction and the location of the orifice are varied. It is shown that the product does not emerge normal to the die face, a factor of importance when dimensional tolerances are small.

J. F. W. Bishop, Scotland

142. Alexander, J. M., and Ford, H., Experimental investigation of the process of expanding boiler tubes, Instn. mech. Engrs., Prepr., 19 pp., Jan. 1956.

The objectives of this work were to examine the tube-expanding process in relation to as many variables as possible and to determine whether there would be any significant "size effect." For these investigations an apparatus was constructed which enables detailed observations to be made of the behavior of a specimen tube-plate joint during expanding.

A typical record is given showing how the strains and mandrel torque develop during expanding. No appreciable size effect was found on the three geometrically similar systems tested. It is shown that the residual strains are much greater on the back than on the front of the plate, leading to lack of parallelism in the joint face, and that the plastic-elastic interface can extend much farther into the plate than was previously thought possible.

Comparison is made between these experimental results and the predictions of a theory proposed by the authors, and it is concluded that higher seat pressures could be obtained if axial extrusion of the tube could be restricted. This finding was confirmed by axially compressing short lengths of tube into a plate, the axial compression causing the tubes to bulge and expand themselves into the plate seat.

From authors' summary

143. Jaoul, B., Influence of intergranular joints upon the cold working of metals (in German), Deformation and flow of solids, Colloquium Madrid, Sept. 26-30, 1955, 13-24. Berlin, Springer Verlag, 1956.

Paper concerns the tension stress-strain curve in metals of single crystal and polycrystalline form. Aluminum of 99.99% is used in the experiments and author proposes empirical formulas for the stress-strain curves based on papers already published.

The curve is divided into first and second stages by a point of inflection in the case of the single crystal, and by a point of transition in the polycrystal, respectively. In the single crystal, the first stage of the curve, wherein light slips take place, forms an upward concave curve and is independent of temperature, while the second stage, in which strain-hardening occurs, is parabolic. When the amount of impurities increases in the single crystal, the first stage becomes elongated. In the polycrystal, the difference between the above two stages is not recognized so clearly as in the single crystal.

How to obtain the stress-strain curve of a single crystal from that of a crystal, and vice versa, is discussed, comparing their characteristics; the answer is very difficult. Author points out this is because of the difference of orientation of crystals and the influence of the grain boundary, i.e., there the tension is absorbed, stresses σ_2 and σ_3 are exerted and shear is decreased. Author attributes these to the difference in the deformation curves.

H. Mii, Japan

144. Wilkinson, R. G., The hot forming of magnesium alloys, *J. Inst. Metals* **84,** 217-228, 1955-1956.

Magnesium-base alloys, having a close-packed hexagonal crystal lattice, are capable of only limited cold deformation, and so, unless the work is very simple, they are usually formed at elevated temperature. This practice involves obvious operational disadvantages, but possesses important compensating features. After detailing the compositions and mechanical properties of the principal wrought alloys and giving data on the effects of heating on the properties, the special requirements in equipment and procedures for hot-forming sheet and extrusions are reviewed.

From author's summary

145. Lewis, T. G., Jr., Ultrafinishing—A new high-precision lapping process, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-77, 8 pp.

A number of important innovations have been made which permit the use of lapping for the production of exceptionally smooth metal surfaces with precise geometrical control. This body of patented techniques, called ultrafinishing, includes the necessary variations in velocity to permit the lapping of soft homogeneous and hard heterogeneous metals. The description of this process covers its similarity to lapping, its fields of application, and the response of materials from a metallurgical point of view. The

application of this process can yield a 0.3 to 0.5-microin. finish rms with an over-all geometry control equal to or better than any commercial finishing method. From author's summary

Hydraulics; Cavitation; Transport

(See also Revs. 30, 46, 92, 125, 129, 174, 338, 347, 348)

Book—146. Wechmann, A., Hydraulics [Hydraulik], Berlin, Verlag Technik, 1955, 300 pp.

Book is intended as an introduction to hydraulics for beginners, and corresponds to that level. Actually, however, many numerical tables and nomograms are given for practical use. Its content does not differ much from old classical textbooks; few new concepts are introduced. Sketches are abundant, particularly on weirs. Foreign names are obviously disfavored. A large list of references, 533 papers, includes only a few foreign titles.

S. Kolupaila, USA

147. Bellman, R., and Pennington, R. H., Effects of surface tension and viscosity on Taylor instability, *Quart. appl. Math.* **12,** 2, 151–162, July 1954.

148. Marchi, E., On uniform movement in open channel flow (in Italian), *Ric. Sci.* **26,** 8, 2448–2473, Aug. 1956.

Author reports the results of a first series of experiments on uniform movement in open channel flows, and particularly those relating to a rectangular canal with smooth walls, and two concrete canals of trapezoidal and triangular cross section, respectively.

For the smooth canal, the tests confirm the reliability, in the examined conditions, of the formulas relating to smooth pipes (with $d = 4R$).

The interpolar curves of the experimental results obtained on naturally rough canals (concrete walls) exhibit on the whole a trend agreeing with that of the similar Colebrook curves, relating to pressure pipes, but at the same time they show a marked influence of the shape of the cross section on the value of the coefficient of friction, at equal roughness and mean radius

P. Franke, Germany

149. Agadzhanyan, G. G., Analytical investigation of the pulsating movement of liquid in pipes (in Russian), *Sb. nauch. tr. Arm. s.-kh. in-ta* no. 8, 187–196, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5115.

Equations are derived of subsonic flow of a compressed liquid in circular pipes at large Reynolds numbers under conditions of small fluctuations of pressure and longitudinal velocities. The following basic assumptions are made: the flow in the turbulent heart of the flow is expressed by Euler's vector equation, the flow in the laminar boundary layer by the Navier-Stokes equation without inertia terms, the flow in the turbulent heart by the adiabatic flow. Also the equation of the heat exchange through the walls of a pipe is determined; no solution is given of the equations obtained. N. A. Kartvelishvili, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

150. Murin, G. A., The hydraulic characteristics of pipeline valve gear (in Russian), *Izv. teplotekh. in-ta* no. 1, 10–14, 1953; *Ref. Zh. Mekh.* 1956, Rev. 4413.

The hydraulic coefficient of a regulating element incorporated in a particular pipe network, i.e., the flow volume in the network according to the amount of valve opening, is customarily determined by the following formula:

$$G = \sqrt{\frac{H\gamma}{3.93\zeta_f/f^2 + C}}; \quad \left(C = \frac{H_c\gamma}{G_2}\right) \qquad [1]$$

where G is flow in kg/hr; H available head, meters water; γ specific gravity of flowing liquid, kg/m³; f variable area of valve opening in mm²; ζ coefficient of resistance of the regulating element referred to the area of the valve opening, determined experimentally; H_c loss of head in the system excluding the regulating element.

The shape of the curve of the hydraulic constant depends on the value of C. Existing types of regulating valves have an approximately linear development of the area of opening according to the amount of motion (stroke) of the valve, and a nearly linear development of the hydraulic constant is obtained only at low values of C.

To simplify determination of the hydraulic constant, a simplified form of Eq. [1] is proposed

$$G = \sqrt{\frac{H\gamma}{A + C}}, \quad \left(A = 3.93\,\frac{\zeta}{f^2}\right) \qquad [2]$$

i.e., f and ζ are replaced by a single quantity A, for which curves of the relationship to the ratio of the degree of opening of the valve to the diameter of the free aperture are given.

Equation [2] is applicable for pressure variations in the regulating elements not exceeding 10% of the initial value.

With decreasing diameters of the free aperture, the efficiency of regulation increases, other conditions being equal, and the curve of the hydraulic constant approaches linearity. The most suitable curve profile corresponds to that of the plug cock; the worst is that for a value with inclined spindle.

K. A. Ushakov, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

151. Neümueller, M., The two fundamental laws of hydrodynamics—the laws of conservation of energy and conservation of momentum in theory and in practice (in German), *Bauingenieur* **31,** 9, 330–334, Sept. 1956.

152. Strasberg, M., The influence of air-filled nuclei on cavitation inception, *David W. Taylor Mod. Basin Rep.* 1078, 25 pp., May 1957.

This report was prepared for presentation at the American Towing Tank Conference held September, 1956 in Washington, D. C., and apparently represents a condensation of the author's Ph.D. dissertation submitted to Catholic University. Those who have a casual to active interest in the subject of cavitation, but without regard to too many details, will find this paper interesting reading as it represents some of the latest thinking on cavitation inception. Those working in the field who are interested in the details would probably find that the author's Ph.D. dissertation would better serve their purposes. More than half of the report comprises a theoretical discussion of the need for and the characteristics of cavitation nuclei in water. Also included is a theoretical review discussion of the two types of cavitation, namely, vaporous and gaseous cavitation.

The real contribution of the paper is a description of the author's experimental investigation of cavitation using ultrasonics. The results of the experimental investigation are somewhat limited because a quiescent undisturbed sphere of water was used as the experimental medium and it would be difficult to extrapolate results to flowing water. Nevertheless, the experimental results lend some support to the theoretical predictions for behavior of

stabilized air nuclei. It is of interest to see a relatively new technique applied in studying cavitation.

R. J. Mindak, USA

153. Saffman, P. G., On the rise of small air bubbles in water, *J. fluid Mech.* **1,** 3, 249–275, Sept. 1956.

Experiments show effect of size, shape, and water impurities on the paths and wake, spiral and zig-zag, of small oblate spheroidal bubbles. Fair agreement exists between experiment and theory and author gives explanations for disagreement.

H. H. Anderson, Scotland

154. Long, L. W., and Conner, N. W., Tests on a broadcrested weir with two different surface adhesion conditions, *N. Carolina State Coll. Engng. School Bull.* no. 61, 26 pp., Mar. 1956.

Measurements of the coefficient of discharge for two sizes of similar rectangular broad-crested weirs, each with two different surface adhesion conditions, were made. The weirs were installed in 6-in. and 4½-in. channels, and were tested with clean glass surfaces and with paraffin-coated surfaces. The results achieved indicate that, at high flow rates, the discharge coefficient is lower for the paraffin surface than for the glass surface, the values being 2.76 and 2.81, respectively, apparently because of differing end contraction effects.

Attention was given to the minimum flow rate at which the nappe could be made to spring clear. A parameter called the adhesion number, similar to Weber number except for the substitution of work of adhesion of the liquid-solid interface for surface energy of the liquid-air interface, was formulated and found to be a valid criterion of conditions necessary for a clear-springing nappe.

The flow rate proved to be unstable through an appreciable range at low flows, the data showing considerable scatter. The scatter obtained in these tests was greater for the glass than for the paraffin surface. A calculation shows that this region is one where the transition from laminar to turbulent flow is to be expected. The flow condition was near critical on the weir crest in the unstable range, so that small variations in energy could account for considerable variation in flow.

The minimum head necessary to produce flow was found to be primarily dependent on channel width, the liquid-solid interface condition being of less importance. The 4½-in. weir manifested a larger minimum head than the 6-in. weir, and the wax-surfaced weir a somewhat higher value than the glass-surfaced weir. These results are in qualitative agreement with a theory given, but quantitative agreement is not of the best for the 4½-in. glass-surfaced weir.

From authors' summary

155. Childs, E. C., Collis-George, N., and Holmes, J. W., Permeability measurements in the field as an assessment of anisotropy and structure development, *J. Soil Sci.* **8,** 1, 27–41, 1957.

Results are reported of determinations of horizontal and vertical hydraulic conductivities of soil by the methods of Childs [AMR **6,** Revs. 3252, 3253] and Kirkham [*Proc. Soil Sci. Soc. Amer.* **10,** 58–65, 1945]. Full experimental details and examples of calculations are given. Anisotropy was found in five out of the thirteen sites of observation.

Importance of structure (as distinct from texture) in determining soil conductivity and of direct measurement of conductivity (as distinct from visual profile observation) are stressed.

Variability of field structure and consequent limitations of the methods are discussed.

D. A. de Vries, Australia

156. Childs, E. C., The anisotropic hydraulic conductivity of soil, *J. Soil Sci.* **8,** 1, 42–47, 1957.

Theoretical paper in which author proves following theorem: "If the conductivity of a material is the sum of a number of contributions each of which has three mutually perpendicular principal axes, then, no matter how the contributors may be oriented relative to each other, the total conductivity also has three mutually perpendicular axes."

Author discusses implications of theorem for the hydraulic conductivity of soils where anisotropy is often due to plane fissures. These can be considered as elements with three mutually perpendicular principal axes. A conducting system of fissures with arbitrary orientation will therefore give rise to a conductivity tensor with three mutually perpendicular principal axes.

D. A. de Vries, Australia

Incompressible Flow: Laminar; Viscous

(See also Revs. 29, 30, 47, 130, 149, 150, 163, 178, 219, 220, 227, 233, 236, 237, 240, 241, 242, 245, 257, 267, 296, 325, 326, 331, 346, 352, 354, 356, 357, 358)

Book—157. Patraulea, N. N., Aerodynamics of permeable surfaces [Aerodinamica suprafetelor permeabile], Rumania, Editura Academiei Republicii Populare Romane, 1956, 173 pp. Lei 7.35.

An account of Rumanian and some Russian investigations. Flow through permeable surface is characterized by change of velocity (refraction equation) and change of pressure (filtration equation) as functions of average velocity across surface. Flow outside surface is assumed inviscid and also incompressible except in one short section on subsonic flow. If outside flow is irrotational everywhere, D'Alembert's paradox occurs. If wake is filled with trailing vortices, then theory predicts drag.

Chapters I to V review theory of vortex motion; discuss equations of refraction and filtration experimentally and theoretically, and propose similarity principle for experiments; and develop linearized theory. Theory is simplified to case of cylindrical wake of vortices parallel to velocity at infinity. Velocity field outside wake is gradient of velocity potential; inside, it is gradient plus induced velocity of vortices. Appropriate boundary-value problem is formulated for velocity potential. Chapters VI to IX discuss plane flow applications to wind breaks (belts of trees); parachutes; permeable lifting surfaces (impermeable airfoil with perforated flap or spoiler); and propulsive disk theory of propellers with infinitely many blades. Chapter X proposes an iterative method to extend calculation from cylindrical wakes to wakes of curved vortices. Chapter XI derives Navier-Stokes equations. Chapter XII develops Oseen theory of viscous flow about permeable surfaces and shows that asymptotic form for vanishing coefficient of viscosity is equivalent to previously introduced linearized theory for cylindrical wakes.

Book is a fairly good introduction to subject. Chief criticisms are: insufficient comparison with experiment; no references to anything but Rumanian and Russian work except for classical topics, such as propeller theory and viscous flow theory.

J. H. Giese, USA

158. Truitt, R. W., Flow in the forward stagnation region of blunt bodies, *J. aero. Sci.* **24,** 5, 380–381, May 1957.

159. Murray, J. D., and Mitchell, A. R., Flow with variable shear past circular cylinders, *Quart. J. Mech. appl. Math.* **10,** 1, 13–23, Feb. 1957.

If the magnitude of the vorticity is proportional to the stream function, the resulting partial differential equation for the flow of a perfect fluid is a simple linear elliptic one, which is separable in polar coordinates. Fourier series describing two flows past a circular cylinder are determined. In the first, the vorticity has opposite sign to the stream function and the upstream velocity profile is a linear combination of decaying and growing exponentials. In the second, the vorticity has the same sign as the stream

function and the upstream velocity profile is sinusoidal in shape. In both cases the displacement of the stagnation streamline upstream is found for a practical range of conditions and a comparison is attempted with what little experimental evidence there is. A. F. Pillow, Australia

160. Batchelor, G. K., A proposal concerning laminar wakes behind bluff bodies at large Reynolds number, *J. fluid Mech.* **1,** 4, 388–398, Oct. 1956.

The model commonly used for the determination of incompressible viscous flow at large Reynolds number Re about a bluff body placed in a uniform stream is the Helmholtz-Kirchhoff free-streamline model. Essential feature of this is the assumption that the fluid velocity be zero everywhere inside what may be called a wake bubble, the boundary of the bubble, or cavity, being a singular surface. The wake bubble may be closed, or open downstream, as shown by Kirchhoff (1869) for the two-dimensional flat plate.

Although this model may be a proper solution of the Navier-Stokes equations for $\mu = 0$ (where μ is the viscosity of the fluid), it is unlikely, according to author, to be the limit as $\mu \longrightarrow 0$ of the solution describing the real flow. Both features of the wake bubble in the model, i.e., open or closed downstream, seem objectionable to author; the latter after a recent investigation by author into the properties of steady flow in a closed region at large Re [*J. fluid Mech.* **1,** 2, 177–190, June, 1956]. It was argued there that viscous stresses acting in the shear layer at the boundary of the region will cause a standing eddy, or eddies, in which the velocity is of the same order of magnitude as outside the wake.

The flow with a closed wake proposed by author in the limit for $Re \to \infty$ is described in detail, giving the properties of the singular surfaces in the fluid behind two-dimensional and axisymmetrical bodies. In all cases, the drag on the body tends to zero as $Re \to \infty$ and this is in contrast to the free-streamline model, which leads to a finite drag.

Reviewer remarks that no mathematical proof is given of the proposed model, nor are examples worked out in detail even for the simplest cases, and so it remains open to question if such a flow does really satisfy the Navier-Stokes equations. Contributions on the problem by Riabouchinsky (1926) and quite recently by Roshko, who proposed a modified Kirchhoff method [*J. aero. Sci.* **22,** 124–132, Feb. 1955], are not examined by author, nor has enough attention perhaps been paid to the experimental information accumulated hitherto. A. Ghetti, Italy

161. Ballabh, R., Steady superposable flows with cylindrical symmetry, *Ganita* **6,** 1/2, 15–21, 1955.

The nonlinear equations of motion permit the vector sum of two flows of an inviscid, incompressible fluid to be another such flow only under certain conditions on the velocity and vorticity components. Typical results: Any two irrotational flows are superposable. An irrotational flow for which a superposable rotational flow exists has constant flow speed along each streamline.
C. Ablow, USA

162. Bayley, F. J., Effect of flow pulsations on form drag, *J. roy. aero. Soc.* **61,** 555, 208–209 (Tech. Notes), Mar. 1957.

163. Tomilov, E. D., The spiral movements of an ideal incompressible fluid (in Russian), *Uchen. zap. Tomskogo un-ta* no. 25, 97–112, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5163.

Examination of the steady flow of an ideal incompressible fluid in which the vortex lines coincide with the stream lines. The condition of parallelism of the vector of the vortex and the velocity, the equation of noncompressibility, and the Bernoulli equations serve as initial equations, the latter being considered correct for the whole region of motion.

Using the curvilinear orthogonal coordinates q_1, q_2, q_3, author examines the case when the vectors of velocity and of the vortex are tangential to the surface $q_3 = \text{const}$. A function of the flow and a function similar to the velocity potential are introduced, for which the corresponding differential equations are obtained.

Finding the flow function in one of the following forms

$$\psi = Q_1(q1)Q31(q3) + Q2(q2)Q32(q3)$$

$$\psi = Q1(q1)[Q21(q2)Q31(q3) + Q22(q2)Q32(q3)]$$

author investigates certain possible flows which may include some studied previously by other authors. There are a number of misprints in the paper. D. E. Dolidze, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

164. Martin, A. I., The aerodynamic variable nozzle, *J. aero. Sci.* **24,** 5, 357–362, May 1957.

Author presents a simplified treatment of flow arising when thin layer of air is injected into main stream to produce aerodynamic variable nozzle. Averaged continuity and momentum equations are employed. Extremely restrictive initial conditions of jet entry temperature, pressure, and density equal to respective stagnation values in main stream limit the applicability of results obtained. Fair agreement of computed and experimental results is found for the few cases presented. R. L. Trimpi, USA

165. Hagy, H. E., and Ritland, H. N., Viscous flow in glass-to-metal seals, *J. Amer. ceram. Soc.* **40,** 2, 58–62, Feb. 1957.

Birefringence measurements were made on glass-to-metal seals with simple geometries during cooling at various rates. Thermal contraction data were also obtained on the metal and on the glass while cooling at the same rates. Using these data, the viscosity of the glass during cooling at a constant rate was calculated. The viscosity deviates markedly from the equilibrium curve and is a function of cooling rate in this temperature region. Viscous flow in the seal is measurable as much as 125 C below the strain point. From authors' summary

166. LeTourneau, B. W., Grimble, R. E., and Zerbe, J. E., Pressure drop for parallel flow through rod bundles, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-134, 8 pp.

Friction factors for flow parallel to a rod bundle have been determined experimentally in a Reynolds-number range from approximately 5000 to 100,000. Three rod arrays were used: namely, a 1.20 pitch-to-rod diameter ratio on a square lattice, and a 1.12 pitch-to-rod diameter ratio on both square and equilateral triangular lattices. Entrance plus exit-loss coefficients, and joint loss coefficients between axially aligned rod bundles also were measured experimentally for tube-sheet end connections. For the square arrays, the effect of tube-sheet flow area on these loss coefficients was investigated. Results are presented in graphical form.
From authors' summary

167. Borisenko, A. I., Characteristic function of a flow about a cascade of circular cylinders (in Russian), *Sb. tr. Labor. problem bystrokhodn. mashini mekhanizmov Akad. Nauk Ukr. SSSR* no. 5 19–26, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5165.

This paper is a continuation of the investigation of the flow of an incompressible fluid about a hydrodynamic cascade of circular cylinders [see *Ref. Zh. Mekh.* Rev. 2093, 1954] and in the method of research is closely associated with the author's work [see *Ref. Zh. Mekh.* Rev. 643, 1953].

A method for finding the characteristic flow function for flow about a cascade of circles is given, as well as the numerical values of the coefficients which make up the function for the relations of the radius of the circles to the pitch of the cascade between 0.1 and 0.5. The comparison which was made for one cascade with a solution according to G. S. Samoilovich's method

[*Prikl. Mat. Mekh.* **14**, no. 2,1950] showed that the values of the coefficient differ only in the fourth degree.
Courtesy Referativnyi Zhurnal A. I. Bunimovich, USSR
Translation, courtesy Ministry of Supply, England

168. Odelsky, E. Kh., Equation of gas motion in a pipeline for remote gas supply (in Russian), *Sb. nauch. rabot. Belorus. politekhn. in-ta* no. 48, 28–39, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5110.

An examination in a unidimensional arrangement of the movement of a gas in a pipeline. Using present-day data on the roughness of pipes and friction in them, author gives a formula for calculating remote gas pipes and makes a comparison with a similar formula which has become known in all countries.

A generalized hydrodynamic characteristic of a gas pipe is introduced which represents the dependence of the relationship of the pressure at the ends of the gas pipe to the length (relative to the length of the whole pipe) over which all the available pressure is expended. D. A. Mel'nikov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

169. Rosenblat, S., and Woods, L. C., A method of cascade design for two-dimensional incompressible flow, *Austral. Aero. Research Comm. Rep.* ACA-58, 30 pp., Mar. 1956.

Method of Woods [AMR **9**, Rev. 3284] for the design of single airfoils in inviscid, incompressible flow is extended to cascades. Given technique allows determination of foil coordinates for a prescribed velocity distribution, and conversely. Example of an actual cascade design is worked out. W. L. Haberman, USA

170. Uvarov, A. P., Increasing the output of suction dredgers by thickening the pulp (in Russian), *Trudi Tsentr. n.-i. in-ta ekonom. i ekspluat. vodn. transp.* no. 5, 110–201, 1955; *Ref. Zh., Mekh.*, 1956, Rev. 1458.

171. Arzhanykh, I. S., Integration of the Gromeko-Lamba equations (in Russian), *Trudi Sredneaz. un-ta* no. 37, 3–14, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5162.

Examination of the general solutions of equations of motion of an ideal incompressible fluid which are written in the Lamba-Gromeko form. The expression for the vector of the absolute velocity in the Lagrange variables and the general integral for these equations were obtained. An integral equation is given for the vector of the relative velocity, and criteria are established for the existence of an integral for steady vortex motion. A particular case of the general solution in the case of collinearity of the vortex and the velocity is given by Gromeka's solution [I. S. Gromeka. Dissertation Kazan 1881; Collected works, Moscow, Izd-vo AN. SSSR, 1952]. The existence of the Gromeka integral is noted for a compressed barotropic fluid. Integral equations of turbulent steady motion of a fluid are given for the case of a parallelism of the vortex of absolute velocity with the vector of the relative velocity.

The integral equations for potential flow about many bodies are examined. The hydrodynamic force is expressed by the solution of the system of integral equations which determines the flow potential. I. E. Tarapov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

172. Liddell, H. F., and Wootten, N. W., The detection and measurement of water droplets, *Quart. J. roy. meteor. Soc.* **83**, 356, 263–266, Apr. 1957.

For measuring the drop-size distribution in a natural fog or a water spray the cascade impactor [May, 1945] provides a ready means of sampling. Air containing the droplets is drawn through a series of nozzles at increasing velocity, and the droplets impact upon plates behind the nozzles according to their inertia: the largest drops impact on the first plate and the smallest on the last plate. This gives a size grading of the drops, making microscopic analysis easier than by having a large range of sizes on one plate. The limitation of this method of sampling has been the capture of the very small droplets, of the order of one micron, and their retention for examination, because of the rapid evaporation of the droplets.

Three methods of making permanent records of traces left by small drops of water have been proposed by May: (a) absolute method by capturing the drops in oil on the slides, which are quickly removed from the impactor and covered with an oiled coverslip before the drops evaporate; (b) using slides coated with a layer of magnesium oxide on which the impacting droplets produce small permanent craters; (c) stain method, using a layer of gelatine in which a dyestuff is dissolved, and which dyestuff is displaced by the water droplet, leaving a distinct ring on the slide.

In this research, a "Naphtenol Green B" dyestuff (produced by Imperial Chemical Industries, Dyestuffs Division) was used and found satisfactory. Method of calibration is described; it was found that the stain remaining after the evaporation of the droplet has a diameter, on the average, about 2.5 times the drop diameter. The method can be used for droplets of less than one micron diameter. K. J. DeJuhasz, Germany

173. Ramsen, J. A., An experimental hydrodynamic investigation of the inception of vortex ventilation, *NACA TN* 3903, 31 pp., Apr. 1957.

An experimental hydrodynamic investigation of some of the parameters affecting the inception of vortex ventilation has been conducted on three modified flat plates of aspect ratio 0.25 differing in scale and thickness ratio.

For all three models, two distinct bubble-formation processes were noted. The speed of inception of the planing bubble in the high angle-of-attack range varied only slightly with angle of attack but increased considerably with increasing depth of submersion. Correlation of this inception speed for all three models was accomplished by using the Froude number and the depth in chords at the leading edge measured to the center line of the longitudinal cross section.

The speed of inception of the planing bubble in the low angle-of-attack range increased significantly with decreasing angle of attack and only slightly with increasing depth of submersion. The speed of inception for the two models differing only in scale was the same, whereas the model differing in thickness ratio was brought into correlation by expressing the speed as a function of the thickness ratio. From author's summary

174. Lovikov, P. F., Influence of the concentration of liquid products on the dimensions of the drops of a liquid and their range of flight (in Russian), *Trudi Leningr. tekhnol. in-ta kholodiln. prom-sti* **7**, 61–64, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5170.

An experimental investigation was made of the influence of a concentration of solid substances in a solution which can be atomized with the aid of a rotating disk upon the average dimension of the drops.

An aqueous solution of gelatine with sugar was supplied to the rotating disk; the drops were caught on a glass plate covered by a layer of a mixture of machine oil and vaseline and then measured under a microscope. During the tests the concentration of dry substances in the liquid which can be atomized varied within the limits of 10 and 45%. The tests showed that with increase of the concentration of the dry substances the average dimension of the drop increases according to a linear law.

On the basis of the data obtained, calculations were made regarding the causes of disturbance of the drying process and

methods of controlling the drying of atomizing appliances.
Courtesy Referativnyi Zhurnal Yu. F. Dityakin, USSR
Translation, courtesy Ministry of Supply, England

175. Leonard, A. S., A preliminary analysis of a turning jet, ASME Fall Meeting, Denver, Colo., Sept. 1956. Pap. 56-F-19, 14 pp.

An attempt is made to analyze a rotating jet of air of the type used in "wind machines" employed for frost protection in citrus orchards. The theory which is developed contains several arbitrary and questionable assumptions. The development depends on experimental data to an important degree, and the final result is thus a semi-empirical correlation of uncertain generality, in the opinion of this reviewer and also of Mr. E. F. Valentine of NACA who aided in the review. No attempt is made to relate the turning-jet properties to the basic problem of the "wind machine" which involves the mechanism by which the air jet (stationary or rotating) causes an exchange between cold air at ground level and warmer air from a layer 20 to 30 feet above the ground.

J. V. Becker, USA

Compressible Flow, Gas Dynamics

(See also Revs. 32, 88, 90, 97, 217, 218, 221, 222, 236, 241, 242, 256, 260, 265, 314, 321, 332)

176. Rakhamonovich, A. N., Flow of a viscous gas in a subsonic jet (in Russian), *Trudl Ufimsk. aviats. in-ta* no. 1, 3-16, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5109.

Examination of the flow of a viscous gas in a subsonic jet in the one-dimensional statement of the problem. The influence of the viscosity is estimated by the polytropic exponent and the efficiency of the equivalent process of expansion.

Author also investigates the flow parameters in a jet in relationship to the coefficient of loss of velocity, which is identically connected with the exponent of polytropy and the efficiency of the equivalent process of expansion. The graphs of these relationships are given for a gas with the adiabatic exponent $K = 1.33$. Some remarks are made on the rate of propagation of sound in a viscous gas. D. A. Mel'nikov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

177. Cabot, L., and Crouzet, J., Determination of the aerodynamic characteristics in a subsonic lofting flight with a model in a wind tunnel, *Rech. aéro.* no. 45, 3-10, 1955.

178. Bevierre, P., Determination of subsonic compressible flow using the incompressible flow case (in French), *Rech. aèro.* no. 46, 3-5, 1955.

179. Levey, H. C., A shock-free airfoil, *J. aero. Sci.* **23,** 12, 1129-1130 (Readers' Forum), Dec. 1956.

180. Wu, C.-H., Flow of compressible fluid past cascade of blades located on any surface of revolution, and method of cascade design (in Chinese), *Mech. Engng. J.* **4,** 1, 21-46, June 1956.

This is author's first known paper since he left the U.S. He is now professor at Tsing-Hua University and member of Chinese Academy of Sciences, Peking.

Paper presents a method of cascade design assuming inviscid, compressible, steady, adiabatic flow with zero absolute vorticity. Design procedure is as follows: (1) Select an arbitrary thin flow-layer contained between two surfaces of revolution. Let the flow conditions of this layer of variable thickness be represented by those on the mean surface or stream surface. (2) Based on desired inlet and exit flow angles, select a streamline on this surface roughly midway between adjacent blades. (Reviewer's note: This is arbitrary since, at this stage, blade geometries are yet unknown.) List coordinates of streamline and thickness of flow layer. (3) Calculate specific mass flow along streamline from continuity equation, density from energy equation, and then, velocity components from kinematic relations. (4) Calculate first and second derivatives of velocity components and density with respect to tangential (angular) dimension, making use of a kinematic relation and condition of zero absolute vorticity. (5) Use these derivatives in Taylor's series to calculate velocity components and density along other lines on stream surface. (6) Coordinates of blade section are obtained by stepwise integration of mass flow, thus determining shape of streamlines on either side of "midway" streamline. Streamlines corresponding to one-half of mass flow between blades (or 60% and 40%, etc.) give shape of blade. (7) Examine velocity and pressure distributions over blade surface. If not satisfactory, redistribute flow on either side of "midway" streamline and obtain new shape. (8) Calculated stream function is used to recheck condition of zero absolute vorticity. This is merely to detect numerical and rounding-off errors incurred during calculations.

Paper also describes procedure for solving direct (performance) problem. A numerical example is given in which performance of a centrifugal compressor was calculated. Compressor had a 48-in. impeller, was previously tested by NACA. Comparison between calculated and test results show good agreement in pressures (better on pressure surface than on suction surface), fair agreement in velocities. Paper contains two tables to aid numerical calculations. These were abridged from *NACA TN 2604* by same author.

Reviewer feels this method would not appeal to most American manufacturers, but is a good procedure to use where design experience and reliable cascade data are lacking.

T. C. Tsu, USA

181. Kammerer, C., Friction factor and adiabatic efficiency for a circular conical compression nozzle (subsonic nozzle) (in German), *Öst. Ing.-Arch.* **10,** 2/3, 197-200, 1956.

182. Kawamura, R., and Saito, H., Investigation of transonic test section with perforated walls, *J. Japan Soc. aero. Engng.* **5,** 36, 1-6, Jan. 1957.

Paper describes preliminary investigation in a model tunnel with test section 5 cm × 4 cm × 20 cm and uniformly distributed perforations (open area 20 to 40%) on the broader sides only. Approximately full-scale Reynolds numbers were achieved by using stagnation pressures up to 21 atm, though scale effect on required bleed was surprisingly small.

R. C. Pankhurst, England

183. Robacker, J. T., and Wheelon, A. D., A note on the solution of a non-linear transonic flow equation, *J. Math. Phys.* **35,** 3, 321-322, Oct. 1956.

184. Fung, Y. C., Some general properties of the dynamic amplification spectra, *J. aero. Sci.* **24,** 7, 547-549, July 1957.

Author investigates some of the general features of the shock spectrum which are little affected by the specific details of the pulse history. At small values of frequency, the first peak of the amplification spectrum may occur after the pulse has returned to zero. At large values of frequency, the first peak tends to occur at the same time as the peak of the pulse. The inverse problem of finding the pulse from the spectrum may not be unique.

B. E. Gatewood, USA

185. Iwasaki, M., and Umetsu, K., Shock tube studies of the development of detached shock waves in transonic flow, Part 1, *J. Japan Soc. aero. Engng.* **5,** 42, 179-182, July 1957.

Experimental results are presented on the development of detached shocks ahead of wedges of 10° and 180° total angle produced in a shock tube at transonic Mach numbers. The following conclusions are drawn: (1) In the early stage, the process of development is considerably influenced by wedge angle; (2) shape of the detached shock is less dependent on wedge angle as the flow Mach number approaches one; (3) similar models produce similar shapes of detached shock at the same Mach number and the same nondimensional delay time.

R. Kawamura, Japan

186. Chapman, D. R., Kuehn, D. M., and Larson, H. K., Investigation of separated flows in supersonic and subsonic streams with emphasis on the effect of transition, *NACA TN* 3869, 109 pp., Mar. 1957.

Authors report on experimental and theoretical research on flow-separation phenomena associated with steps, bases, compression corners, curved surfaces, shock-wave boundary-layer reflections, and configurations involving leading-edge separation. Results were obtained from pressure-distribution measurements, shadowgraph observations, high-speed motion pictures, and oil-film studies. The maximum scope of measurement encompassed Mach numbers between 0.4 and 3.6 and length Reynolds numbers between 4,000 and 5,000,000. The principal variable controlling pressure distribution in the various separated flows was found to be the location of transition relative to the reattachment and separation positions.

From authors' summary by A. K. Oppenheim, USA

187. Palmer, H. B., and Hornig, D. F., Rate of dissociation of bromine in shock waves, *J. chem. Phys.* **26,** 1, 98–105, Jan. 1957.

The rate of dissociation of bromine, pure and diluted with argon, was measured from 1200 K to 2225 K in shock waves, in order to study the mechanism of elementary reaction processes. The absorption coefficient of Br_2 was measured over the same temperature range. In the case of dissociation produced by Br_2–A collisions the reaction rate constant is reproduced over a range of 10^{27} by a collision theory equation. The activation energy is approximately equal to the dissociation energy of Br_2, the frequency factor is about 6% of that deduced from the collision frequency, and it appears that both the vibration and rotation of the Br_2 contribute energy to the dissociation. Br_2 is roughly twice as efficient as A in producing dissociation at high temperatures. For dissociation produced by Br_2–Br_2 collisions the measurements are in agreement with a rate constant in which the activation energy equals the dissociation energy, the steric factor is from 1% to 10%, and five to seven square terms (e.g., the two vibrations and one to three rotations) contribute to the energy of dissociation.

From authors' summary

188. Jahn, R. G., The refraction of shock waves at a gaseous interface, *J. fluid Mech.* **1,** 5, 457–489, Nov. 1956.

Paper describes an extensive investigation of the refraction of a shock wave at a gaseous interface. Experimental results for two gas combinations, air/CO_2 and air/CH_4, at two shock strengths, $\xi = 0.85$, $\xi = 0.30$, are compared with theoretical predictions of Polachek and Seeger. Author believes that the gas combinations and shock strengths used are adequate for a significant test of refraction theory. Excellent agreement is obtained between experimental results and theoretical predictions throughout the region of regular refraction.

An interesting feature of paper is discussion of the several types of flows produced during irregular refraction. Author shows how exceeding each of the critical angles of regular refraction logically leads to the observed flows.

Reviewer believes paper to represent a significant contribution to our understanding of shock-wave phenomena.

R. E. Duff, USA

189. Sakurai, A., Propagation of spherical shock waves in stars, *J. fluid Mech.* **1,** 4, 436–453, Oct. 1956.

Analysis concerns the propagation of spherical shock waves, caused by instantaneous central explosion, through self-gravitating polytropic gas spheres such as stars. The shock strength is variable. Solutions are obtained as power series.

A. M. Kuethe, USA

190. Trimpi, R. L., A theory for stability and buzz pulsation amplitude in ram jets and an experimental investigation including scale effects, *NACA Rep.* 1265, 24 pp., 1956.

Diffusor performance being reduced by flow instability, it is essential for efficient operation that buzzing be either avoided or its amplitude held at a small value. A theory for approximate buzz pressure amplitude is developed from a linearized equation of motion for small perturbations superimposed on a one-dimensional isentropic steady flow. Ramjet is hereby considered as a constant-area duct with exit constriction, the proper boundary condition there being a constant Mach number, corresponding to a choked nozzle. This yields a variable perturbation amplitude along the ramjet, as actually shown by experimental surveys, from which a further assumption on maximum pressure amplitude at ramjet midpoint is made for determining the perturbation amplitude spectra. Theory has been found in good agreement with experience. In addition, cold-flow tests at 1.94 Mach number of models with 3.15 : 1 scale factors and 4.75 : 1 Reynolds number ratios with several supersonic diffuser configurations showed only small performance variations between geometrically similar models, buzz originating at nearly same conditions. Furthermore, no appreciable variation in stability limits of any of the models was found when combustion-chamber length was increased by a factor of three. Velocity profile in combustion chamber at both Reynolds numbers was appreciably influenced by an angle of attack of 0.5°.

Apparatus, test procedure, and results are extensively discussed, and a general critical review of existing, contrasting stability theories and criteria is presented, as well as a discussion of Sterbentz-Evvard resonator theory, showing its applicability limitations. Report is a valuable contribution to prediction of ramjet operating conditions.

P. Schwaar, France

191. Frederiksen, E., Resonance behavior of nonlinear one-dimensional gas vibrations analyzed by the Ritz-Galerkin method, *Ing.-Arch.* **25,** 2, 100–112, 1957.

Author makes an approximate analysis of the following problem: The gas column within a cylindrical pipe, closed at one end, is excited to vibrations by a harmonically oscillating piston, located at the other end; what is the response when nonlinear gas properties are taken into account? Experiments made by E. Lettau, and published in *Deutsche Kraftfahrtforschung* **39,** 1939, have disclosed that such vibrations may be nonlinear and include shock waves travelling back and forth. Author solves the problem using the Ritz-Galerkin method of approximation. He finds the criterion for the presence or absence of shock, and his results agree with experiment.

T. Leser, USA

192. Sedney, R., Laminar boundary layer on a spinning cone at small angles of attack in a supersonic flow, *J. aero. Sci.* **24,** 6, 430–436, 455, June 1957.

Magnus effects are determined for small spin rates. Howarth, Mangler, and Blasius transformations are applied and stream-function parameters are expanded in powers of the spin-rate parameter. Result indicates minute Magnus forces such that experimental verification would be difficult.

J. R. Baron, USA

193. Nicolas, J., Experimental study of pulsatory flow in a supersonic air intake (in French), *Rech. aéro.* no. 58, 23–28, May–June 1957.

Paper describes flow behavior in and around simple ducts as observed by means of high-speed shadowgraphic motion pictures and pressure records. Model, consisting of straight pipe with cylindrical or conical inlet diffuser, was tested in free jet at $M = 1.47$. Investigation covered effects of duct length, cowl lip shape and diffuser angle. Flow coefficient K (ratio of capture area to inlet area) was controlled by plug-valve adjustment of exit area. Critical K (value of K at onset of pulsations) was found to be rather insensitive to changes of cowl lip shape and duct length. Pressure records reveal two pulsation frequencies: a high frequency component (2200 to 2400 Hz), which is particularly noticeable at high K, and a low frequency component which is more noticeable at low K. Frequency of latter component is function of duct length, while that of former components is substantially independent of duct configuration.

J. V. Foa, USA

194. Cohen, Doris, The warping of triangular wings for minimum drag at supersonic speeds, *J. aero. Sci.* **24,** 1, 67–68 (Readers' Forum), Jan. 1957.

195. Le Grives, E., Fabri, J., and Paulon, J., Diagrams for the calculation of air to air supersonic injectors (in French), *ONERA NT* 35, 27 pp., 1956.

196. Jones, R. T., Theory of wing-body drag at supersonic speeds, *NACA Rep.* 1284, 7 pp., 1956.

The relation of Whitcomb's "area rule" to the linear formulas for wave drag at slightly supersonic speeds is discussed. By adopting an approximate relation between the source strength and the geometry of a wing-body combination, the wave-drag theory is expressed in terms involving the areas intercepted by oblique planes or Mach planes. The resulting formulas are checked by comparison with the drag measurements obtained in wind-tunnel experiments and in experiments with falling models in free air. Finally, a theory for determining wing-body shapes of minimum drag at supersonic Mach numbers is discussed and some preliminary experiments are reported.

From author's summary by A. R. Mitchell, Scotland

197. Seibold, W., Theoretical estimation of the spoiler effectiveness in supersonic flow (in German), *Jahrbuch Wissenschaft. Gesellsch. Luftfahrt,* 192–204. Braunschweig, Friedr. Vieweg & Sohn, 1955.

Study is made of flow about spoilers to be used for generating control forces on wings or for deflecting a jet exhaust. Calculation of shock location, standing upstream of spoiler, agrees favorably with experiment. Theoretical prediction of the pressure coefficient on the upstream side of the spoiler shows reasonable agreement with experiment. Based on these results, side-force coefficients and jet deflection angles are predicted theoretically in terms of stream Mach number, spoiler angle and geometry. Estimates of the viscous effects on the side-force coefficients indicate that, within the approximation of the calculation method given in the paper, these effects can be accounted for by using an effective spoiler height $h_{eff} = h\,(1 - \delta/h)$, where δ is the boundary layer displacement thickness.

For trim tabs author suggests using triangular spoilers.

R. W. Detra, USA

198. Van Dyke, M. D., On Stokes' stream function in compressible small-disturbance theory, *NACA TN* 3877, 15 pp., Feb. 1957.

In this note, author points out an important feature of Stokes streamfunction in perturbation theory of compressible flows. It is shown, on the basis of flow over a cone, that the correct first-order approximation leads to a nonlinear differential equation, and that the boundary condition imposed on mass flux, rather than on tangency on velocity, for both linear and nonlinear solutions invariably yields inaccurate results at high Mach numbers. The effects of nonlinearity in the first-order equation were found to be essential in higher approximations, without which the result may well prove disastrous.

Y. H. Kuo, China

199. Tyler, R. D., One-dimensional treatment of non-uniform flow, *Aero. Res. Counc. Lond. Rep. Mem.* 2991, 18 pp. + 3 figs., 1957.

The errors arising in the case of a one-dimensional treatment of a flow in a circular duct have been calculated and presented graphically for various boundary-layer thicknesses and Mach numbers. The errors are found to vary from 2½ to 5% for $1 \leq M \leq 2$, when the assumption is made that the boundary-layer thickness is 10% of radius at exit. The error in the total pressure is larger and is about 10% for $M = 2$. General equations are presented for larger Mach numbers. Author suggests the use of these correction factors in evaluating kinetic energy and momentum flux in ducts where the mean density and velocity are known.

Reviewer feels that the assumptions are reasonable for short ducts where the flow is laminar and the results will be useful. In other cases, the same method can be modified to arrive at the requisite correction factors.

Y. V. G. Acharya, India

200. Krzywoblocki, M. Z., On axially symmetric flow through annular bodies in compressible flow, *Bül. Istanbul tekn. Univ.* **10,** 1, 60–83, 1957.

Axially symmetric flow of incompressible fluid is easily studied by means of elliptic functions, and bodies can be constructed superimposing source rings to uniform flow. In linearized theory of compressible fluid flow, analogous results are to be expected, for, replacing radial coordinate r by $(1 - M^2)^{\frac{1}{2}} r$, one obtains again the Laplace equation of incompressible fluid problems. Author's approach is equivalent to a linearization. Method is illustrated by numerical examples.

Reviewer points out a curious result: source ring has a limiting torus around itself. This does not happen in classical linearization, and seems to be typical of general nonlinear equation.

G. Moretti, Argentina

201. Graham, E. W., Examples of wave drag calculation by application of Fourier analysis about a streamwise axis, *Douglas Aircr. Co. Rep.* SM-19529, 29 pp., Jan. 1956.

When computing supersonic wave drag there are two different ways in which the singularity distribution can be Fourier analyzed about a streamwise axis. The first one is the familiar method of Lomax and Heaslet [*J. aero. Sci.* **23,** no. 12, 1956] of analyzing the distribution projected on the axis in the Hayes' manner. The second one, which is discussed in the present paper, consists of analyzing the original distribution in space. Author shows how the Fourier components in the two different methods are related. As in the Lomax and Heaslet method the Fourier components are non-interfering in their wave drag contributions.

The method presented is useful in treating configurations with axial symmetry. The wave drag of a ring wing is analyzed, and it is shown that a distribution of radial force proportional to $\sin \phi$, where ϕ is the angular variable, gives the lowest possible wave drag for a given lift. The method might also be of some practical use for other types of configurations as is shown for a low-aspect-ratio rectangular wing. The first two terms in the Fourier series were shown to contribute 93% of the correct total wave drag in this case.

M. Landahl, Sweden

202. Eckert, E. R. G., Hartnett, J. P., and Birkebak, R., Simplified equations for calculating local and total heat flux to non-isothermal surfaces, *J. aero. Sci.* **24,** 7, 549–551, July 1957.

A note directed to the development of approximate algebraic expressions for the local heat flux and total heat transfer to an external surface. The expressions derived can be applied to both laminar and turbulent flow situations where the temperature is varying with position in any prescribed manner. Solution requires a knowledge of the temperature distribution, heat-transfer coefficient under isothermal conditions, and the pressure gradient. Simplifications required to obtain the expressions include introduction of empirical expressions for nonisothermal heat-transfer coefficients and numerical integration. Authors estimate agreement with more exact methods is 5% for local heat flux equation and 1% for integrated heat-transfer equation.

T. J. Connolly, USA

203. Rose, P. H., and Riddell, F. R., An investigation of stagnation point heat transfer in dissociated air, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 213–248.

An investigation of heat transfer from air to a blunt point (radius = 0.66 cm) at stagnation in the hypersonic flow behind the step shock wave produced in a shock tube. Authors used both thick platinum resistance calorimeter gages and "thin film" platinum gages mounted on pyrex blunt tips. Neither the thickness nor surface area of these gages is listed in the report. Authors present a simple and adequate theory for thick gage operation and give results that show heat transfer is constant 10 microseconds after shock passage for both gage types. Measurements were made in air up to shock incident velocities of Mach 18 with estimated stagnation temperatures of 8000 K and dissociation of 50%. Maximum heat-transfer rate was about 50 Kw/cm^2. Authors present a theoretical stagnation heat-transfer equation, derived by assuming an equilibrium boundary layer (i.e., infinite recombination rate), which agrees well with their experimental data. Unfortunately, the derivation and most of the attendant assumptions may be found only in a company report by the authors. The authors discuss the effect of "frozen" boundary-layer theory (i.e., no recombination) and conclude: if the wall is catalytic toward recombination, heat transfer will not be greatly changed from the "equilibrium" boundary-layer value. The authors discuss flight simulation and conclude that their shock tube can simulate stagnation conditions for flight from 20,000 to 120,000-ft altitude and 5000 to 25,000-fps velocity.

R. A. Strehlow, USA

204. Blokh, E. L., Flow of a viscous gas between two moving parallel cylindrical surfaces of arbitrary form (in Russian), *Prikl. Mat. Mekh.* **20,** 1, 116–119, Jan./Feb. 1956.

When the temperatures of the moving cylindrical surfaces are prescribed as constant, the problem becomes independent of the coordinate z along the cylinders. The energy equation then has a Crocco-type solution even for an arbitrary Prandtl number. The problem reduces to the solution of two-dimensional Laplace's equation for the unknown $H = \int_0^u \mu du$, where μ is the viscosity coefficient dependent on the temperature and hence on the axial velocity u. Author displays the variation of friction with relative Mach number in the general case and gives detailed formulas for the Couette flow and the flow corresponding to two confocal elliptical cylinders.

M. V. Morkovin, USA

205. Makofski, R. A., Charts for the analysis of flow in a whirling duct, *NACA TN* 3950, 21 pp., May 1957.

The analysis is based on steady one-dimensional gas flow with allowance for wall friction and wall heat transfer. The nonlinear differential equation obtained is numerically integrated for a range of parameters. In reviewer's opinion, the charts should be extremely useful where applicable, e.g., tip-mounted helicopter propulsive systems.

H. C. Levey, Australia

206. Schmidt, C. M., and Hanawalt, A. J., The effect of an arbitrary distribution of surface temperatures on heat transfer in the compressible laminar boundary layer, *J. aero. Sci.* **24,** 1, 73–74 (Readers' Forum), Jan. 1957.

207. Carter, W. J., Optimum nose shapes for missiles in the superaerodynamic region, *J. aero. Sci.* **24,** 7, 527–532, July 1957.

The mechanics of the kinetic theory of gases is employed to describe the drag force on the nose of a missile moving in the superaerodynamic region of the atmosphere. Three separate cases are considered—ideal specular reflection, specular-type reflection from a slightly rough surface, and surface absorption followed by random emission of the striking molecules. The calculus of variations is employed to obtain the differential equation of the nose shape which minimizes the drag force for each of the three cases. The resulting differential equations are then solved by a numerical procedure. The drag coefficients for the optimum nose shapes are likewise determined, and these are compared with the drag coefficients given by other nose shapes. It is further shown that the drag coefficients arising when specular-type reflections occur are significantly dependent on the nose shape. When surface absorption followed by random emission occurs, the drag coefficient is not strongly dependent on either the missile nose shape or the fineness ratio of the nose.

From author's summary by E. W. Price, USA

208. Kubota, T., Inviscid hypersonic flow over blunt-nosed slender bodies, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 193–210.

Kubota considers a slender body placed in a uniform hypersonic stream of an inviscid, non-heat-conducting gas. The criterion for hypersonic small-disturbance flow is $M_\infty \gg 1$ and δ (thickness ratio of body) < 1. Expressing all the independent and dependent variables in terms of M and δ ($\bar{u} = (uu_\infty^{-1} - 1)\delta^{-2}$, etc.), introducing them into full equations of motion, and discarding terms which contain δ^2 explicitly furnishes hypersonic flow equations. In his first approximation, Kubota derives shock conditions in case of infinite Mach number and expresses the flow velocity, pressure, and density in terms of these conditions. This inserted into the hypersonic flow equations furnishes the first set of equations solved numerically.

In his second approximation, Kubota expresses velocity, pressure and density in terms of series of negative powers of Mach number, ϵ; by substituting these expressions into the hypersonic equations, and equating to zero the powers of ϵ separately, one obtains a sequence of equations for the functions defining the dependent variables. This enables one to take account of a finite Mach number and of the similarity properties of a class of bodies. Only second approximations are considered, referring to nonlifting, symmetric blunt-nosed bodies. The experiment carried out in GALCIT Hypersonic Wind Tunnel at $M = 7.7$ shows fair agreement.

The general conclusions are: for an infinite Mach number, the Newtonian flow theory is quite accurate for certain shapes; the second approximation indicates that the pressure field varies little with M, while density varies appreciably with M; tests show importance of boundary layer and its influence on shock shape.

M. Z. Krzywoblocki, USA

209. Bradley, J. C., General properties of normal shock waves at hypersonic speeds, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 211–230.

The purpose of this paper is to determine the thermal properties of the air behind a normal shock wave. The starting point is the random kinetic energy of air molecules approximately assumed to be a sum of energy contributions from each degree of freedom: translation, rotation, vibration, electronic excitation. The equation of state contains the dissociation function in form given by Bethe and Teller. Elementary results of quantum statistic mechanics and the quantum mechanical partition function are used to account for excited electronic states. The model of the air is assumed to be 22% of oxygen and 78% of nitrogen. In the shock wave, a large part of the directed motion of the molecules is converted to random motion by collisions among the molecules and this random energy is evenly distributed over all the degrees of freedom of the molecules. After the molecules absorb sufficient energy internally through binary collisions, thermodynamic equilibrium is achieved. The time and distance through which this occurs are called relaxation time and distance, respectively. These assumptions allow the writer to calculate the following results ordered in tables for altitudes 0, 100,000 and 200,000 ft and for a temperature range from 2000 K to 26,000 K: dissociation function, relaxation distance and time according to Bethe and Teller, energy contributions of each constituent and total energy content, temperature, pressure and density behind the shock wave. A gross error results from applying the equation of state of a perfect gas in the shock wave region. When account is taken of absorption of energy by dissociation and electronic excitation of the air molecules, both the pressure and density behind a normal shock wave are higher than predicted by the perfect gas law, and the temperatures are lower; the thickness of shock is found to be negligible up to 200,000 ft and $M = 20$. Higher electronic states (ionization) should be included, but this is prevented by the lack of knowledge of ionization energies.

M. Z. Krzywoblocki, USA

210. Dorrance, W. H., and Norell, R. G., Correlation of cone-cylinder normal force and pitching moment data by the hypersonic similarity rule, *J. aero. Sci.* **24,** 5, 371–377, 392, May 1957.

Experimental data taken from tests of cone cylinders at a range of supersonic Mach numbers in the Naval Ordnance Laboratory 40-cm-by-40-cm wind tunnel are correlated in this paper using the hypersonic similarity rule. The uniqueness of this rule was experimentally established for cone cylinders by taking measurements on hypersonically related bodies at different Mach numbers. Once uniqueness was experimentally established, it was possible to correlate data taken for a wide variety of cone cylinders in such a way as to provide charts for estimating normal force, normal force distribution, and pitching moment for cone cylinders for Mach numbers greater than 1.5, cone semivertex angles up to 14 degrees, and angles of attack up to 15 degrees, providing laminar flow exists over the body.

From authors' summary by H. Ramm, USA

211. Bond, J. W., Jr., Some aerophysics problems connected with hypersonic flight, G-E Techn. Forum, New York, N. Y., Apr. 3, 1956. 7 pp.

Wave Motion in Fluids

(See also Revs. 92, 334)

212. Parmakian, J., Water-hammer design criteria, *Proc. Amer. Soc. civ. Engrs.* **83,** PO 2 (*J. Pow. Div.*), Pap. 1216, 8 pp., Apr. 1957.

Design criteria for including the effects of water hammer in turbine penstock and pump discharge line installations are outlined. Various possible conditions of operation are enumerated and suitable factors of safety are assigned to each contingency. Typical examples are included. From author's summary

213. Marchi, E., Waves with a long period (in Italian), *Energia elett.* **33,** 8, 783–791, Aug. 1956.

Author treats of waves similar to sinus-curves with period T long enough for the influence of the resistance to exceed overwhelmingly the nonpermanence of the movement. These prerequisites are met, e.g., in the case of waves of a river in flood. In the first approximation, the dynamic equation is expressed as

$$F = K Q^n - \alpha Q_t$$

with the factor

$$\alpha = n^3/(2g\,i)\,[i_c/i - (1 - 2n + n^2)/n^2]$$

which is only a function of the characteristics of the channel and of the uniform movement. The values of n and K are obtained from the formulas of velocity. For example, there follows from the equation of Brahms-Chézy $n = 2/3$ and from that of Gauckler-Manning $n = 3/5$.

The equation

$$A = e^{-\gamma x} \quad \text{with} \quad \gamma = \alpha(2\pi/T)^2$$

together with that of the continuity permits studying the attenuation of the waves, whatever their highness may be.

From author's summary

214. Dyrbye, C., Hydraulic briefs: designation of the breaker-point for a progressive wave on decreasing depth, *Houille blanche* **11,** 3, 415–418, July/Aug. 1956.

The investigation is confined to plane progressive waves and makes use of second-order classical theory; the effects of the law of decrease in depth and of reflection (flat beaches) are neglected. The conditions for breaking are derived by considering the horizontal motion of particles, and are then presented in graphical form. The theoretical results obtained are in good agreement with observations in the laboratory and in nature.

From author's summary

Turbulence, Boundary Layer, etc.

(See also Revs. 33, 159, 192, 202, 236, 237, 262, 264, 293, 299, 351)

215. Swanson, A. G., Buglia, J. J., and Chauvin, L. T., Flight measurements of boundary-layer temperature profiles on a body of revolution (NACA RM-10) at Mach numbers from 1.2 to 3.5, *NACA TN* 4061, 40 pp., July 1957.

Total-pressure and total temperature profiles of the boundary layer at one length station of the model are measured at 15 points along the trajectory of the rocket-propelled model. Graphs of these results are given together with the reductions to static-temperature and Mach-number profiles, taking into account the static pressure at the test point. These measured profiles agree very well with the theoretical results of Crocco. The skin-friction coefficients obtained from the measurements are in fair agreement with the theoretical flat-plate values of van Driest. The transition from laminar to turbulent flow occurs about $Re = 15 \times 10^6$.

S. F. Erdmann, Holland

216. Reshotko, E., and Beckwith, I. E., Compressible laminar boundary layer over a yawed infinite cylinder with heat transfer and arbitrary Prandtl number, *NACA TN* 3986, 86 pp., June 1957.

Numerical solutions to the equations for the compressible laminar boundary layer have been obtained for the flow in the stagnation region of an infinite cylinder in yaw for large free-stream Mach numbers and large yaw angles. The wall temperature was varied from zero to twice the stream stagnation temperature. Solutions are given for Prandtl numbers of 1 and 0.7. The results

indicate that the heat-transfer coefficient decreases with yaw angle about as the square root of the cosine of the yaw angle for subsonic Mach numbers and somewhat less than the cosine of the yaw angle for Mach numbers greater than 2.

From authors' summary by C. F. Bonilla, USA

217. Englert, G. W., Estimation of compressible boundary-layer growth over insulated surfaces with pressure gradient, *NACA TN* 4022, 35 pp., June 1957.

The incompressible boundary-layer theory of Truckenbrodt was extended using a modified Stewartson-type transformation to include compressible boundary-layer development over insulated surfaces. The variation of turbulent shear stresses with Mach number of the bounding potential stream was considered using the reference-temperature method of Eckert. The explicit technique of Truckenbrodt for determining the profile parameter in the incompressible theory was unchanged so that the profile parameter as well as the momentum thickness can still be evaluated by simple quadratures in the present theory.

The method is applicable to two-dimensional and axisymmetric, laminar and turbulent boundary layer, and accounts for the pressure gradient along the wall for both compressible and incompressible flow.

Experimental measurements of the boundary layer on small axisymmetric bodies on the wall of a supersonic wind tunnel were compared with theoretical predictions. For most cases studied, agreement between experiment and theory was within 10%.

From author's summary by M. H. Bertram, USA

218. Trimpi, R. L., and Cohen, N. B., An integral solution to the flat-plate laminar boundary-layer flow existing inside and after expansion waves and after shock waves moving into quiescent fluid with particular application to the complete shock-tube flow, *NACA TN* 3944, 180 pp., June 1957.

Authors consider problem of unsteady laminar boundary-layer flow inside and behind centered rarefaction waves as well as behind shock waves. A modified Kármán-Pohlhausen approach is applied to customary two-dimensional, unsteady boundary-layer equations (x, y, t) after these equations have been transformed to a conical coordinate system (ξ, y, t), where the conical parameter is defined as $\xi = x/a_e t$, the subscript denoting a reference state. This is an assumption that all outer-flow inviscid solutions are functions of ξ only. Resulting hyperbolic differential equations are integrated in closed form for flow behind shock waves and integrated numerically for flow inside or behind an expansion fan. This solution is used to predict the unsteady laminar boundary layer existing at all points in an air-air shock tube for $\gamma = 1.4$ and $Pr = 0.72$. Approximate solutions, with assumption of zero-thickness expansion wave, were obtained for an air-air shock tube, $Pr = 0.72$ and $Pr = 1.0$; helium-air shock tube, $Pr = 0.72$; and hydrogen-air shock tube, $Pr = 0.72$. Velocity profile, skin friction, and heat-transfer results generally are in good agreement with those obtained by H. Mirels [*NACA TN* 3401, AMR **9**, Rev. 206; and *TN* 3712]. Limitations of assumption of zero-thickness expansion wave are indicated. Reviewer refers reader to recent paper by H. Mirels and W. H. Braun [*NACA TN* 4021] for an extension of previous work by Mirels.

A. Ritter, USA

219. Martin, J. C., On Magnus effects caused by the boundary-layer displacement thickness on bodies of revolution at small angles of attack, *J. aero. Sci.* **24,** 6, 421–429, June 1957.

The effect of the boundary-layer displacement thickness on Magnus effects is investigated by analyzing the laminar boundary layer on a cylindrical portion of a slender body of revolution. A solution of the three-dimensional boundary-layer equations is obtained. The displacement thickness is found and then is used to calculate the Magnus force and center of pressure by slender-body theory.

The Magnus effects caused by turbulent boundary layers are investigated under certain assumptions, and values from the resulting expression for the center of pressure are compared with data obtained from range firings.

From the author's summary by R. C. Roberts, USA

220. Squire, L. C., The three-dimensional boundary-layer equations and some power series solutions, *Aero. Res. Counc. Lond. Rep. Mem.* 3006, 10 pp. + 12 tables + 1 fig., 1957.

The boundary-layer equations are derived for a very general coordinate system, and various theorems hitherto only proved in more restrictive systems are extended to this general system. The particular case of streamlines of zero geodesic curvature is investigated in detail and a solution of such a flow found by a power series method. Finally, Howarth's stagnation-point solution is extended to second-order terms by numerical investigation.

From author's summary by A. Balloffet, USA

221. Gadd, G. E., The numerical integration of the laminar compressible boundary layer equations, with special reference to the position of separation when the wall is cooled, *Aero. Res. Counc. Lond. curr. Pap.* 312, 17 pp., 1957.

Author transforms Crocco's equations for the viscous stress and the enthalpy to new variables in such a way that the resulting functions are free of singular points. He then carries out a numerical integration by means of finite difference approximations and shows that a fair accuracy can be obtained even with large intervals. Several numerical examples are given for non-zero leading edge velocities with the aim to determine the position of the separation point under adverse pressure gradients.

K. Pohlhausen, USA

222. Becker, E., Boundary layer growth in and behind an expansion shock wave (in German), *Ing.-Arch.* **25,** 3, 155–163, 1957.

When a plane expansion shock wave advances along a flat wall into stationary fluid, the front of the wave travels at the speed of sound in the stationary fluid. The thickness of the shock-wave zone increases as the shock wave advances, and the expanded fluid behind the shock wave attains a steady velocity in a direction opposite to that of the shock-wave motion. Across the shock-wave zone, the fluid velocity varies continuously from zero at the wave front to the velocity of the expanded fluid at the back of the wave zone.

The fluid velocity along the wall, both within the shock-wave zone and in the expanded fluid, causes the growth of a boundary layer on the wall which may cause significant deviations from the pressure, velocity, and density distributions predicted from the equations of motion for one-dimensional frictionless compressible flow.

The author sketches the development of approximate expressions for the displacement, momentum, and boundary-layer thicknesses for the shock-wave zone and the expanded fluid, for both laminar and turbulent flow. Parabolic velocity profiles are assumed for streamline flow and the 1/7th-power law for the turbulent case. No attempt is made to predict transition from laminar to turbulent flow. Unfortunately, certain important logical steps are missing from the discussion, so that the reader cannot follow the author's derivation nor grasp the significance of the results quantitatively without extensive study of other references on shock-wave phenomena.

A. W. Gessner, USA

223. Weber, H. E., The boundary layer inside a conical surface due to swirl, *J. appl. Mech.* **23,** 4, 587–592, Dec. 1956.

An analysis to determine the boundary-layer thickness due to swirl flow in an axially symmetric conical surface. The velocity in the meridian plane and the peripheral velocity in the boundary layer are assumed to be represented in the conventional power

laws for the laminar and turbulent case. Results of the boundary-layer thickness variation with distance from the vertex of the cone and with different values of the circulation are plotted for the laminar and turbulent cases.

Author simplifies the problem by assuming pressure gradients and velocity normal to conical surfaces to be zero in the boundary layer. S. Eskinazi, USA

224. Truckenbrodt, E., A simple approximate method for the calculation of the laminar boundary layer with suction (in German), *Forsch. Geb. Ing.-Wes.* **22,** 5, 147-157, Sept. 1956.

Comparing approximate methods of Schlichting [AMR **3,** Rev. 1547] and Torda [AMR **6,** Rev. 1979], author observes that momentum-thickness-parameter derivative can be approximated by sum of two linear functions of pressure gradient and suction velocity parameters. Method for calculating laminar, incompressible boundary-layer characteristics, developed on this basis, is relatively simple and agrees well with existing exact solutions such as that of Iglisch for a flat plate with uniform suction [AMR **3,** Rev. 550]. As an interesting example author considers boundary-layer development on axisymmetric body resulting from the superposition of a source and a uniform rectilinear flow. Two cases of uniform suction are treated; one in which suction begins at the stagnation point and one in which suction begins at point of maximum potential velocity. Results indicate that momentum thickness and wall shear distributions in latter case rapidly approach those of former case for the same uniform suction velocity.

H. E. Brandmaier, USA

225. Sinha, K. D. P., The direction of flow in the laminar boundary layer on an infinite yawed cylinder, *Aero. Res. Counc. Lond. curr. Pap.* 295, 37 pp. + 19 figs., 1956.

Paper extends previous work [AMR **9,** Rev. 2995] to include information concerning velocity field inside boundary layer. As before, the chordwise external flow is given by $U_0 x^m$, and a definite suction distribution assumed so as to preserve the character of "similar" solutions. The resulting system of two ordinary differential equations has been solved previously for different values of m and of the suction parameter. The present report gives detailed information about primary and secondary flow profiles inside the boundary layer. The influence of pressure gradient and suction on secondary flow instability (Owen-Randall criterion) is discussed. A. von Baranoff, France

226. Eichelbrenner, E. A., and Oudart, A., Laminar separation in three dimensions (in French), *Rech. aéro.* no. 47, 11-14, Sept.-Oct. 1955.

The word separation, when applied to flow around a solid boundary, is associated with the limit between the boundary layer and the secondary flow that takes place downstream of such surface. The origin of the word is clear in the two-dimensional case, because no secondary motion could be enclosed by the separation surface without a real separation of the main flow from the solid boundary. For a three-dimensional flow, however, it is possible to obtain such a secondary flow enclosed by an envelope without a real separation of the main flow, because the fluid can surround the geometrical boundary formed by the body and the envelope. In that case, the streamlines close to the wall, instead of being turned away from the body, become tangent to the intersection of the envelope and the solid boundary.

This pattern occurs when the pressure gradient along the solid boundary is different from zero in the direction of the main flow. When the gradient is equal to zero, separation takes place as for the two-dimensional case. For the first behavior, flow inside the envelope has no important velocities normal to the solid boundary, and can be studied with the theory of the three-dimensional laminar boundary layer. Authors have confirmed these criteria both analytically and experimentally.

Some good photographs are presented of the case of an ellipsoid in which air streamlines have been visualized by injecting streaks of milk through convenient holes in the surface of the body.

A. Balloffet, USA

227. Eichelbrenner, E.-A, and Oudart, A., Method of calculation of three-dimensional boundary-layer with application to spindle-shaped body with nonzero angle of attack (in French), *ONERA Publ.* no. 76, 49 pp., 1955.

An attack on the problem of the three-dimensional laminar boundary layer is made by means of "streamline coordinates" and what the authors call a "prevalence" or predominance principle. This principle asserts that in the boundary layer the velocity normal to the streamlines can be neglected compared with the velocity along the streamlines. This is reasonable in view of the fact that the normal velocity vanishes on the body and at the edge of the boundary layer.

The solution then proceeds by a Pohlhausen method, the streamwise velocity being represented by a quartic in the usual way and the normal velocity by a cubic.

Application is made to the flow past an ellipsoid of revolution—a prolate spheroid with ratio of axes 6:1—with its axis inclined at 10° to the mainstream. The external streamlines are calculated and drawn on a model, which also shows the line of separation, calculated from the criterion "The separation line is the envelope of the limiting streamlines" on the surface of the body.

The model was tested by H. Werlé in the water tunnel of Châtillon; the flow was visualized by the emission of milky fluid from points on the surface of the body. Agreement was found to be good, especially as regards separation.

In this study, authors assume that the boundary-layer thicknesses in the two directions are equal. Although expressing misgivings about this, they quote in support such authorities as Prandtl and Gruschwitz. Timman and his co-workers, though using the prevalence principle in some of their work, do not make this assumption. Reviewer believes that the latter work may therefore be more accurate. J. C. Cooke, England

228. Zysina-Molozhen, L. M., On the character of the transition from the laminar to the turbulent flow region in the boundary layer (in Russian), *Zh. tekh. Fiz.* **25,** 7, 1280-1287, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 12 pp.).

A semi-empirical method of determining the influence of the transition region on boundary-layer flow is developed. The method is used to calculate the losses in a turbine and a compressor cascade, which compare well with experimental values.

The considerable variation of flat plate test data from the assumed function in the transition region makes the reviewer wonder if the accurate results for flow with a pressure gradient are fortuitous or general. Recognition of the transition region, however crude, should improve on methods which ignore its effect.

G. M. Ketchum, USA

229. Schlichting, H., Suction in aerodynamics (in German), *Jahrbuch Wissenschaft. Gesellsch. Luftfahrt,* 19-28, 1956.

The possibilities of improving the aerodynamic properties of airfoils by means of boundary layer suction are summarized. Continuously distributed suction through the porous surface of the wall is the only effective method. More recent experimental work has confirmed the theoretical results. A reduction in drag up to 50% of the frictional drag and more seems to be within the realm of practical possibility. Research work on the increase of the maximum lift coefficient has shown, during the early 1930's, extremely promising results regarding the flapped wing of moderate thickness, with suction applied through a slot to the gap of the flap. Two airplanes with suction, built at the Aerodynamische

Versuchsanstalt Göttingen as a check for the wind-tunnel tests, have confirmed the wind-tunnel tests. More recent wind-tunnel experiments in Great Britain and USA have shown also that, with respect to increase in maximum lift, continuously distributed suction is superior to suction applied through slots.

From author's summary by H. Gortler, Germany

230. Rivlin, R. S., The relation between the flow of non-Newtonian fluids and turbulent Newtonian fluids, *Quart. appl. Math.* **15,** 2, 212–215, July 1957.

Paper presents interesting qualitative remarks and tentative suggestions regarding the turbulent flow of Newtonian fluids, based on examples which might be considered to indicate some similarity between the turbulent behavior of Newtonian fluids and the laminar flow of non-Newtonian liquids obeying stress laws given in a previous paper by Rivlin [AMR **8,** Rev. 3656]. One of the several examples is the existence of secondary flows in the cross-sectional planes of the turbulent flow of Newtonian fluids in pipes of noncircular cross section. Such cross flows were also found by the author in previous papers for the laminar flow of "nearly" Newtonian fluids. One of the suggestions of the paper is that turbulent flows might show elastic effects under suitable experimental conditions. It is also suggested that normal stress effects might be expected in turbulent flows since in non-Newtonian fluids these effects can be contributed to secondary flows.

Reviewer feels that the careful wording of the paper will eliminate misinterpretations and this intriguing paper will be considered what it intends to be, i.e., a tentative suggestion.

V. G. Szebehely, USA

231. Schwarz, W. H., and Corrsin, S., Some effects of isotropic turbulence on a pendulum at moderate Reynolds number, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 421–439.

Experiments of a preliminary nature were carried out with a spherical bob pendulum placed in a turbulent field. The mass and diameters of the pendulum and the intensity and scale of the grid turbulence were varied while the r.m.s. displacement of the pendulum was observed.

It was found that the r.m.s. displacement was very much larger than could be expected from a simple theory based on the directional fluctuation of the drag force on the sphere. Authors concluded that the transition of the boundary layer on the sphere must be profoundly affected by the disturbances and it may act as an amplifier causing asymmetrical pressure distribution.

L. S. G. Kovasznay, USA

232. Traugott, S. C., and Yeh, H., The influence of solid body rotation on screen-produced turbulence, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 401–419.

Paper describes measurements of turbulent intensities, Reynolds shear stresses, and microscales in grid-produced turbulence, with and without a superimposed solid body rotation. This flow is of considerable theoretical interest and is relevant to practical problems of turbulent flow with curved streamlines. Rotation causes a reduction in radial intensity and an increase in circumferential intensity, a small positive correlation between radial and circumferential velocity, a reduction in the microscale of radial fluctuations, and an increase in the microscale of axial fluctuations.

The theoretical discussion of the results is in terms of the equations for the individual turbulent intensities and Reynolds stresses and is necessarily indeterminate. The demonstration that the correlation between radial and circumferential velocity is zero depends on neglect of mixing processes and is in error.

A. A. Townsend, England

233. Lamson, P., Measurements of lift fluctuations due to turbulence, *NACA TN* 3880, 38 pp., Mar. 1957.

The power spectra of the fluctuating lift of a rigid wing in turbulent flow were measured, the aerodynamic admittance was obtained, and comparisons were made with existing theory. Aspect ratio and span were varied by means of movable end plates.

From author's summary by R. M. Crane, USA

234. Domm, U., A hypothesis concerning the mechanism of turbulence generation (in German), *Dtsch. Versuchsanstalt Luftfahrt E. V. Rep.* no. 23, 15 pp. Sept. 1956.

A vortex system is considered as a medium causing the transition from laminar flow to turbulent flow. In the case of the boundary-layer flow of the flat plate, the vortex system is assumed as a single row of vortex street in the vicinity of the wall. In this paper, the process of transition is discussed by studying the instability of this vortex street. Reviewer thinks that this paper is interesting in spite of its shortness. T. Okamoto, Japan

235. Fetting, F., Flow fields in fluidized beds based on heat-transfer measurements (in German), *ZVDI* **98,** 29, 1692–1693, Oct. 1956.

A simple model is developed of the flow field in order to explain a number of heat-transfer phenomena in fluidized beds. The heat flux from the heated wall first goes through a contact boundary layer where the solid particles have practically no movement, then through a turbulent mixing layer to the main center part of the fluidized bed. J. A. Businger, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 67, 157, 158, 164, 177, 194, 196, 201, 205, 210, 211, 229, 233, 259, 261, 269)

236. Kuo, Y. H., Problems in modern aerodynamics (in Chinese), *Scientia* no. 10, 289–295, 1957.

This article by Y. H. Kuo (formerly Professor of Aeronautical Engineering at Cornell University) gives a brief survey of present-day aerodynamics. The topics discussed are: transonic aerodynamics; supersonic aerodynamics; hypersonic aerodynamics, with additional sections on the effects of viscosity dissociation and ionization; magneto-aerodynamics; and heat transfer at high speeds. The article is apparently written for pointing out the general direction of research in modern aerodynamics.

C. C. Lin, USA

237. Crabtree, L. F., Effects of leading-edge separation on thin wings in two-dimensional incompressible flow, *J. aero. Sci.* **24,** 8, 597–604, Aug. 1957.

Separation-bubble phenomena in two-dimensional flow around airfoils are reviewed and interpreted in the light of the results obtained by a number of investigators. The separation bubble is the result of laminar separation near the leading edge and subsequent reattachment of the flow. Transition to turbulent flow in the detached layer and consequent turbulent mixing, which cause the reattachment, are discussed. The pressure recovery to be expected in a bubble and the conditions under which long or short bubbles occur are considered in the light of a physical mechanism involving transition and turbulent mixing. The over-all problem is divided into three partial problems: (1) Flow in the bubble; (2) turbulent mixing region; (3) external inviscid stream. Typical effects of angle of attack and Reynolds number on the bubble, and of the bubble on the pressure distribution, maximum lift, and stalling characteristics are illustrated. A general mechanism of leading-edge stall has emerged from the physical picture of laminar separation bubbles. Several aspects of separation phenomena require further study, among which are three-dimensional separations. G. B. Schubauer, USA

238. Jousserandot, P.-Q., Influence of flow in the neighborhood of leakage on the aerodynamic characteristics of a high speed wing (in French), *Rech. aéro.* no. 56, 21–32, 1957.

239. Donely, P., The measurement and assessment of repeated loads on airplane components, NACA, 3rd Meeting of the Structures and Materials Panel of AGARD, 22 pp. + 30 figs., Apr. 1956.

240. Gronau, K.-H., Theoretical and experimental investigation of wings in side slip, particularly for sweptback and delta wings (in German), *Jahrbuch Wissenschaft. Gesellsch. Luftfahrt,* 133–150, 1956.

A method for calculating asymmetric lift distributions over yawed wings of arbitrary planform in incompressible flow is developed using Truckenbrodt's extended lifting-line theory [Z. *Flugwiss,* **1,** 31–37, 1953]. Rolling and yawing moments due to sideslip are determined for a number of rectangular, delta, and swept wings. To compare theory with experiment, systematic six-component measurements were carried out for swept and delta wings of various aspect ratios. The experimental results are in good agreement with the values of the derivatives obtained by the theory. S. Lampert, USA

241. Truckenbrodt, E., A method for the calculation of lift distribution for wings at sonic speeds (in German), *Jahrbuch Wissenschaft. Gesellsch. Luftfahrt,* 113–130, 1956.

A method is presented for numerical calculation of the lift distribution over wings at sonic speeds by a method of summation. The required coefficients are given. Method is applicable for wings of arbitrary planform, twist and camber, and is based on slender-body theory with thickness effects neglected. Compression shock effects are also neglected. S. Lampert, USA

242. Weber, J., and Hawk, A. C., Theoretical load distributions on fin-body-tailplane arrangements in a side-wind, *Aero. Res. Counc. Lond. Rep. Mem.* 2992, 23 pp. + 6 tables + 17 figs., 1957.

This work belongs to a series of investigations of the mutual interference between the separate parts of combinations of lifting surfaces and bodies. This paper is a continuation of an earlier note by the first author where the interference between fin and fuselage was considered. The solutions presented here are concerned only with the load distribution when the wing is at a finite angle, for arrangements for which the resulting trailing vortex system produces constant induced velocity along the wing span. Calculations are made for fin-tailplane-fuselage arrangements in a pure side wind, giving side force distributions along the height of fin and body, and the spanwise lift distribution on tailplane and body. The method is applicable to tailplanes of straight cross section without dihedral, except for surfaces near the fin-fuselage junction where the conformal transformation requires a curved cross section.

Numerical values are given in charts and tables of the induced sidewash, the side force, and the lift distributions, for a series of representative cases. Although the calculations are restricted to incompressible flow, the results can be applied to subcritical compressible flow by the Prandtl-Glauert procedure.

R. M. Spath, USA

243. Goroshchenko, L., Relationships between top speed, ceiling and air temperature (in Russian), Vestn. rozd. flota no. 12, 36–45, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3506.
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

244. Fraser, D., Icing experiments in flight and comparisons with wind tunnel testing, *AGARD Publications* AG18/P8, 126–134, June 1955.

Icing investigations can be made under simulated icing conditions in a tunnel or in flight, or in natural icing in flight. All three methods have their advantages and disadvantages, and the use of only one method may prove misleading. In general, icing tunnel tests are required for evaluation over the full range of probable icing conditions, and flight tests in natural icing are essential to give true quantitative results.

From author's summary

245. Klein, H. An aerodynamic screen for jet engines, *Douglas Aircr. Co. Rep.* SM 22625, 25 pp. + illus., Mar. 1957.

The problem of jet engines picking up material from aircraft runways has been investigated experimentally. It was found that a downward directed jet prevented the formation of the vortex responsible for sucking up materials. This appears to provide a satisfactory, safe, and economical solution to the problem. The flow phenomena giving rise to the material pick up, the flow characteristics of the "blowaway jet," and the test results on the working device are described. Data are given regarding the necessary air quantities and pressures.

From author's summary

246. Levey, H. C., The "ground" interference of a carrier deck, *Aero. Res. Lab., Melbourne, Austral. Note* ARL/A. 158, 9 pp. + 3 figs., Jan. 1957.

An estimate is made of the "ground" interference effect of the deck of an aircraft carrier. It is shown that in the extreme case of wing span equal to deck width the induced upwash is of the order of 20% less than the usual ground interference value. Thus the landing characteristics of an aircraft should not be markedly affected. From author's summary

247. Powell, R. D., Jr., The effect of forward-flight speed on the propulsive characteristics of a pulse-jet engine mounted on a helicopter rotor, *NACA TN* 3855, 23 pp., Jan. 1957.

The effect of rotor forward speed on the propulsive characteristics of a blade-tip-mounted helicopter-type pulse-jet engine has been determined in the Langley full-scale tunnel for various engine rotational speeds.

The effect of forward speed was to decrease mean engine thrust and increase engine specific fuel consumption. For a representative cruising forward-flight condition of 90 fps and an engine velocity of about 370 fps, a reduction in propulsive thrust of about 5.5% and an increase in minimum specific fuel consumption of about 4% from that obtained at zero forward speed are shown. For the most severe condition tested, a tip speed of 425 fps and a forward speed of 101 fps, a 50% reduction in thrust and a 100% increase in engine specific fuel consumption were obtained. Whirling at a rotor forward speed of zero resulted in about a 10 to 20% reduction in engine thrust from that obtained in tests of a non-whirling engine as the centrifugal acceleration was increased from 178g to 286g. From author's summary

248. Baum, Q., Flight loads during combat training, *Aircr. Engng.* **28,** 330, 262–263, Aug. 1956.

249. Drischler, J. A., and Diederich, F. W., Lift and moment responses to penetration of sharp-edged traveling gusts, with application to penetration of weak blast waves, *NACA TN* 3956, 85 pp., May 1957.

The lift and moment responses to penetration of sharp-edged traveling gusts are calculated for wings in incompressible and supersonic two-dimensional flow, for wide delta and rectangular wings in supersonic flow, and for very narrow delta wings. By using the two-dimensional indicial-lift functions, some calculations are made of normal acceleration response at two mass ratios.

The results indicate that the forward speed of the gusts have a large effect on the response functions. For incompressible flow,

peaks exist in the early portion of the lift response, which may be much larger than the steady-state value. The peaks encountered at supersonic speeds are less pronounced and rarely exceed the steady-state value.

An indication is given of the relation between gusts traveling at supersonic speeds and blast waves. The manner in which the calculated response can be used in a linearized approach to the blast load problem is outlined.

The results presented can be used to calculate the loads and motions of an airplane or missile dropped from another airplane, of an airplane crossing the wake of or flying past another airplane, of a helicopter blade traversing the wake produced by itself and the other blades of the rotor, of an airplane flying through a sonic "boom", and of an airplane encountering or being overtaken by a blast wave. R. M. Spath, USA

250. Young, A. D., and Neumark, S., Recovery from high-speed dive (in German), *Jahrbuch Wissenschaft. Gesellsch. Luftfahrt*, 98–112, 1956.

On the basis of step-by-step calculations of the recovery of three different aircraft from a high-speed dive, three different approximate methods for calculating the recovery after the initial oscillatory phase have been developed.

L. Landweber, USA

251. Lessing, H. C., Fryer, T. B., and Mead, M. H., A system for measuring the dynamic lateral stability derivatives in high-speed wind tunnels, *NACA TN* 3348, 42 pp., Dec. 1954.

252. Cheers, F., Note on the change from multi-cell to single-cell rotating stalls, *J. aero. Sci.* **24,** 5, p. 392, May 1957.

253. Gustafson, F. B., and Tapscott, R. J., Methods for obtaining desired helicopter stability characteristics and procedures for stability predictions, *NACA TN* 3945, 28 pp., Feb. 1957.

In the first part of this report a brief review is presented of methods available to the helicopter designer for obtaining desired stability characteristics by modifications to the airframe design. The discussion is based on modifications made during the establishment of flying-qualities criteria and includes sample results of theoretical studies of additional methods.

The conclusion is reached that it is now feasible to utilize combinations of methods whereby stability-parameter values are realized which in turn provide the desired stability characteristics.

Part II reviews some of the methods of predicting rotor stability derivatives. The procedures by which these rotor derivatives are employed to estimate helicopter stability characteristics have been summarized. Although these methods are not always adequate for predicting absolute values of the stability of the helicopter, the effects on stability of changes in individual derivatives can generally be estimated satisfactorily.

From authors' summary

254. O'Hara, F., The forward take-off of a helicopter, *Aero. Res. Counc. Lond. Rep. Mem.* 2937, 12 pp. + 11 figs., 1957.

Author extends Squire's classical theory of steady motion [*Rep. Mem.* no. 1730, 1936] to accelerated motion of a single-rotor helicopter during forward take-off. The equations of motion along and normal to the flight path are set up but can only be solved by numerical integration; author obtains simpler approximate solutions by splitting the motion into stages during which either the disk attitude or the flight speed is constant. Variable disk attitude to keep the flight speed constant must be assumed, e.g., when the helicopter accelerates near the ground to a speed safe in case of engine failure and then climbs at this speed. The solutions for the various aspects of take-off are plotted in 10 convenient graphs. Ground effects, not available for forward speed, may be taken from hovering data, [AMR **8,** Rev. 197] and should be accurate enough at low take-off speeds.

Reviewer believes that the report is a valuable contribution to the general performance theory of helicopters.

G. R. Graetzer, USA

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 162, 233)

255. Kappus, R., and Clerc, B., Calculation of the modes and natural frequencies of a delta wing mounted on an airplane free in space, from the experimental influence coefficients (in French), *Rech. aéro.* no. 57, 37–40, Mar.-Apr. 1957.

A method of replacing the wing and fuselage by a discrete system of masses given by the authors in an earlier paper [title source, no 46, 31–33, 1955 is applied to a specific case. The calculated modes and frequencies are compared with experiment, and the error for the frequencies is found to be of the order of 15%. This is thought to be due to the flexibility of the fuselage, and it is concluded that this flexibility must be taken into account if significant errors are to be avoided. L. C. Woods, Australia

256. Miles, J. W., Supersonic flutter of a cylindrical shell, *J. aero. Sci.* **24,** 2, 107–118, Feb. 1957.

Paper is presented as a sequel to an earlier formulation of two-dimensional panel flutter problem. The problem is here treated as that of dynamic instability of traveling waves on a cylindrical shell exposed to an external supersonic airstream and containing an internal fluid. It is assumed that the thickness of the shell wall is small and that the radius of curvature is everywhere large compared with the wave length. The latter hypothesis allows the shell to be approximated as plane in establishing the interaction of the surface wave with the external air.

The general equations of the propagation of the transverse wave are then derived. Matching the transverse component of the general plane wave with the transverse wave, the resulting acoustic pressure is calculated: the pressure resulting from the disturbance in the internal fluid is determined in the hypothesis of incompressible internal fluid; the equilibrium of such pressures with inertia and elastic actions provides the required equation. Thence, the stability equation is derived and discussed. Furthermore, the empty isotropic shell is treated, and the minimum thickness/radius ratio required to prevent flutter in supersonic airstream is determined, for such particular case. The stability criterion and the negative damping ratio when this criterion is not met are determined. It is shown that the negative damping ratio decreases monotonically with an increase in structural damping, but structural damping cannot prevent instability and may render an otherwise stable motion weakly unstable.

In appendix, the accuracy of plane wave approximation is discussed. Also, long wave-length instability is discussed.

I. P. Santini, Italy

Propellers, Fans, Turbines, Pumps, etc.

(See Revs. 68, 69, 125, 170, 172, 180, 190, 203, 252, 270, 273, 278, 292, 324, 355, 358)

Flow and Flight Test Techniques

(See also Revs. 177, 193, 215, 244, 251, 310, 319)

257. Debeauvais, F., Feidt, R., Gebel, C., and Sackmann, L.-A., The D.F.G. capillary micro-flowmeter (in French), *Publ. sci. tech. Min. Air, France,* no. 64, 23 pp., 1957.

The flowmeter is suitable for accurate measurement of steady flows of liquids of order 1 cc/sec. Method depends essentially on measurement of pressure drop in long capillary tube. Instrument is calibrated at one fixed temperature by measuring quantity of liquid passing through tube in known time. Due to end effects the calibration curve is parabolic and not linear; the two constants defining the parabola are determined graphically. Authors show simply from equations that effect of a change of viscosity with temperature can be interpreted as a shift of the origin of the calibration curve. Hence, if variation of viscosity of liquid with temperature is known, flow can be determined simply from measurements of pressure drop and temperature, using single calibration curve obtained at one known temperature. Diameter of capillary tube is required only to check that Reynolds number is subcritical, and need not be known accurately.

W. A. Mair, England

258. Wolter, H., The principal measuring-error limits in schlieren and interference methods (in German), *Ann. Phys. Leipzig* **19**, 1/2, 1a-9b, Nov. 1956.

Author compares error limits in schlieren and interference methods for refractive index and thickness measurements. Analysis indicates that at maximum sensitivity, on uncertainty principle basis, the lower limits of sensible error in the systems are approximately equal. Measurement errors are, however, usually greater in the case of the schlieren technique. In addition, the measurement-error lower limit attainable with the interference method is essentially equal to the sensible error lower limit, which can be calculated.

J. S. Arnold, USA

259. Sagot, J., Balance for the measurement of pitching damping at transonic and supersonic speeds (in French), *Recb. aéro.* no. 57, 7-10, Mar.-Apr. 1957.

A balance, to be mounted on the tunnel wall and therefore especially suitable for half-models, is described which can be adapted to several wind tunnels of the ONERA. The torsiometer axis which is chosen as reference axis for the pitching moments generally coincides with the center of gravity of the model. An electric motor provides a sinusoidal oscillation of the model about an axis 0.06 m from the torsiometer axis, with constant amplitude of 5°, with a frequency to be chosen between 5 and 40 Hz and to be controlled by thyratrons. The torsiometer used is of the classical crossed strip gages type. Principle of measurement and exploitation of measured data are described. Three experimental results are given: c_{m_α} and $c_{m_q} + c_{m_{\dot\alpha}}$ as functions of reduced frequency at Mach number $M = 0.25$ for two wings of NACA 65 A 008 profile, with aspect ratio $A = \infty$ (showing good agreement with theory) and $A = 2.25$, and, finally, $c_{m_q} + c_{m_{\dot\alpha}}$ as function of Mach number ($0.75 < M < 1.3$) for the half-model (scale 1 : 60) of a certain swept-wing airplane, the graph shown being the average value for each M of a small region of reduced frequencies. There is a top value of $c_{m_q} + c_{m_{\dot\alpha}}$ at $M \sim 0.9$, and a change of sign between $M = 1.2$ and $M = 1.3$.

H. Behrbohm, Sweden

260. Fisher, L. J., and Hoffman, E. L., Ditching investigations of dynamic models and effects of design parameters on ditching characteristics, *NACA TN* 3946, 58 pp., Feb. 1957.

Data from ditching investigations conducted at the Langley Aeronautical Laboratory with dynamic scale models of various airplanes are presented in the form of tables. The effects of design parameters on the ditching characteristics of airplanes, based on scale-model investigations and on full-scale ditchings, are discussed. Various ditching aids are also discussed as a means of improving ditching behavior.

From authors' summary

261. Gibson, F. W., Determination of the structural damping coefficients of six full-scale helicopter rotor blades of different materials and methods of construction, *NACA TN* 3862, 19 pp., Dec. 1956.

Measurements were made of the internal or structural damping characteristics of six full-scale helicopter rotor blades of six different materials and methods of construction. Structural damping coefficients are presented for the first three flapwise bending modes, the first torsion mode, and the first chordwise bending mode for all blades.

The structural damping coefficients for all blades are presented in tabular form together with the frequencies, amplitudes of oscillation, and approximate stresses in flapwise bending. Approximate torsional stresses are also given for one blade. Typical samples of the data are plotted to show effects of material of construction, mode shape, and amplitude on the structural damping coefficients.

The contribution of structural damping to the total damping of the blades is discussed for several aerodynamic conditions in order to point out situations where structural damping is significant.

From author's summary

262. Morkovin, M. V., On transition experiments at moderate supersonic speeds, *J. aero. Sci.* **24**, 7, 480-486, July 1957.

Author discusses wind-tunnel experiments with a hot-wire anemometer of transition on a flat plate at Mach number 1.76. Contribution of disturbances from the plate and wind tunnel are investigated. Relative importance in these tests of the many possible causes of transition is described, with the conclusion that more refined experimental work is necessary to improve the inadequate state of knowledge on transition.

W. F. Davis, USA

263. Turner, P. E., Wind tunnel tests on a 6% two-dimensional aerofoil in the transonic speed range, *Aero. Res. Lab., Melbourne, Austral. Rep.* A.99, 18 pp. + 26 figs., Aug. 1956.

Pressure distributions, schlieren photographs of the flow near the trailing edge, and wake traverse profiles are presented for a modified NACA 64-106 airfoil at zero incidence in the Mach number range 0.5 to 1.04.

A comparison is made between results obtained with natural transition and with transition artifically fixed by roughness close to the leading edge. It is shown that natural transition produced greater lift, a higher Mach number at which the peak value of lift occurred, and a more abrupt subsequent loss of lift than did fixed transition. In both cases, however, the lift had fallen to approximately zero by $M = 1.0$.

Variation of lift with Mach number is discussed with reference to shock position, with the aid of the schlieren photographs.

From the wake traverse profiles, the characteristic "step" obtained at Mach numbers above 0.9 is explained in terms of the shock-wave pattern near the trailing edge.

From author's summary

264. Schuh, H., and Winter, K. G., The R. A. E. 4-ft × 3-ft experimental low-turbulence wind tunnel Part II. Measurements of turbulence intensity and noise in the working-section, *Aero. Res. Counc. Lond. Rep. Mem.* 2905, 19 pp., 1957.

Measurements are given of the turbulence in the working section together with measurements of the noise.

With all the screens fitted in the tunnel, the intensities of lateral components are of the same order as the longitudinal component and range from about 0.01% to 0.03% of the mean speed.

Frequency analyses have shown the longitudinal components to consist of fan frequencies and a low-frequency contribution at about 5 to 10 cps. The lateral components consist almost entirely of a similar low-frequency contribution.

With all the screens in the tunnel, the low level of turbulence is confined to a restricted area near the center of the tunnel, with flashes of high-intensity turbulence spreading a considerable distance from the walls.

Noise measurements with the hot-wire microphone in the middle of the working section showed that above a tunnel speed of 150 ft/sec the longitudinal component consisted mainly of noise. Some measurements were also made with the hot-wire microphone in the turbulent boundary layer on the walls.

From authors' summary

265. Schmitz, G., Contribution to the velocity corrections in wind tunnels in compressible subsonic flow (in German), *Z. Flugwiss.* **5**, 6, 169–172, June 1957.

Using linearized theory and approximating the model by a doublet, the blockage corrections for circular and two-dimensional open jet test sections are expressed in the usual way as Fourier integrals. The deformation of the jet boundary is also considered. Numerical examples are discussed. S. B. Berndt, Sweden

266. Sandahl, C. A., and Faget, M. A., Similitude relations for free model wind-tunnel studies of store-dropping problems, *NACA TN* 3907, 26 pp., Jan. 1957.

Two methods are presented for dynamically scaling store models for wind-tunnel store-dropping studies. For each method the model and prototype Mach numbers are assumed to be necessarily equal and the Reynolds number effects are assumed to be negligible. The light-model method gives exact simulation of the store motions except that the vertical displacements are deficient. This deficiency is reduced as the vertical ejection velocity is increased or it can be eliminated by accelerating the parent model upward at the instant of store separation. The heavy-model method, in which the parent model is stationary, gives complete simulation of the store motion except that the short-period longitudinal oscillation is too poorly damped; this defect is of no serious consequence during the first phase of a drop because the time during which the store is critically close to the parent model is generally small compared with the period of the longitudinal oscillation. The heavy-model method is generally recommended for store-dropping studies; however, it is often impossible to make the models sufficiently heavy and with the proper moment of inertia. If such is the case, the light-model method is required.

A brief description of the method of conducting store-dropping tests in the preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., is given.

From authors' summary

267. Arie, M., and Rouse, H., Experiments on two-dimensional flow over a normal wall, *J. fluid Mech.* **1**, 2, 129–141, July 1956.

Velocity, pressure, and turbulence behind a series of normal plates in the uniform test section of an air tunnel were measured, the oscillation of the wake being prevented in all but one test through use of symmetrically located tail plates. To simulate infinite fluid conditions for flow over a wall on a plane boundary, the test section profile was modeled along two streamlines by approximating the flow outside the eddy by potential flow past a Rankine oval and taking into account the influence of the boundary layer on the tunnel walls. Test results obtained thus for flow over a plate were corrected numerically for the influence of the wake behind the plate by replacing it through a distribution of doublets along the tunnel axis. A significant difference is indicated between the characteristics of flow past an isolated plate with an oscillating wake and those of flow over a wall on a plane boundary, where a standing eddy is being formed.

From authors' summary by A. Kuhelj, USA

268. Hartley, D. E., Haines, A. B., and Staff of RAE High Speed Wind Tunnel, Tests in the RAE 10-ft × 7-ft high-speed wind tunnel on drop tanks fitted to two swept back wings, *Aero. Res. Counc. Lond. Rep. Mem.* 2951, 45 pp., 1956.

Report describes tests made in the Royal Aircraft Establishment 10-ft × 7-ft high-speed wind tunnel on drop tanks, fitted to two wings, having the same planform with a sweepback of 40 deg and an aspect ratio of 3.5, but differing in thickness/chord ratio, being 10% and 8.5% thick, respectively.

Part I compares the results obtained with the drop tanks mounted in two alternative positions on the 10% thick wing: under the wing at about mid-semi-span, supported by an 8.5% thick strut or, alternatively, at the wing tip in a mid-wing position. Part II compares the results obtained with several different types of under-wing installation, *e.g.*, with different designs of strut or, alternatively, dispensing with the strut and fitting the tanks directly onto the lower surface of the wing. The latter are referred to as "nacelle-type" tanks. Most of the tanks had a fineness ratio of 8 : 1.

The original under-wing and tip arrangements gave about the same drag increment for $C_L = 0.2$ throughout the Mach-number range; at $M = 0.88$ and $R = 2.8 \times 10^6$, this was about 20 lb drag at 100 ft/sec for two full-scale tanks. For values of C_L less than about 0.2, the tip installation was superior. The reduction in top speed, owing to the drag of these tanks, might amount to about 0.03 to 0.04 in Mach number.

The tip arrangement has several important disadvantages: (i) it causes appreciable shifts in the aircraft c.g. and neutral point; (ii) buffeting may occur in flight at high Mach numbers and moderate lifts (possibly even under cruising conditions); (iii) the performance of the basic wing is not quite restored after the tanks have been dropped owing to the substitution of a square for a curved tip—the corresponding reduction in top-speed Mach number is about 0.01.

The last two disadvantages could probably be eliminated by designing a square tip to have a good performance at high speed, *e.g.*, by the introduction of camber and twist there.

Suggestions for improving the tip and under-wing installations are made. An improved performance would be expected in both cases if the tank were moved so that the upper surface of its nose were faired smoothly into the wing upper surface and its intersections with the lower wing surface were modified to coincide with the streamline over the wing. This suggestion, applied to tanks fitted near mid-semi-span was investigated in the tests reported in part II with most promising results.

At high Mach number, the loss in performance with the nacelle-type tanks at values of C_L of 0.2 or less was only about half that with the best strut-supported arrangement, *e.g.*, the reduction in drag-divergence Mach number (M_D) was only about 0.025. The gain from shaping the junction to follow the streamline over the wing was not large for the tank tested (90 gallons on a wing of about 35-ft span) but might be greater for a larger store.

No definite opinion can be given regarding the scheme in which the tank was held by three small struts instead of a single large strut because of the large scale effect likely with the results on this arrangement.

Part II also includes some measurements of the normal force and pitching moment on the tank itself, when supported by a single strut. The results suggest that for stressing, the effects of Mach number are not as severe as assumed previously but that the nose-down pitching moment at low C_L, which has to be corrected for by jettison fins, increases appreciably with Mach number.

From authors' summary

269. Milwitzky, B., Lindquist, D. C., and Potter, D. M., An experimental study of applied ground loads in landing, *NACA Rep.* 1248, 34 pp., 1955.

An experimental investigation has been made of the applied ground loads and the coefficient of friction between the tire and the ground during the wheel spin-up process in impacts of a small

landing gear under controlled conditions on a concrete landing strip in the Langley impact basin. The basic investigation included three major phases: impacts with forward speed at horizontal velocities up to approximately 86 fps, impacts with forward speed and reverse wheel rotation to simulate horizontal velocities up to about 273 fps, and spin-up drop tests for comparison with the other tests. In addition to the basic investigation, supplementary tests were made to evaluate the drag-load alleviating effects of prerotating the wheel before impact so as to reduce the relative velocity between the tire and the ground.

In the presentation of the results, an attempt has been made to interpret the experimental data so as to obtain some insight into the physical phenomena involved in the wheel spin-up process. From this study it appears that the conditions of contact between the tire and the ground, and consequently the magnitude of the coefficient of friction, vary greatly during the course of an impact and with different impact conditions. The value of the coefficient of friction appears to be appreciably influenced by a number of factors, such as the instantaneous skidding velocity, the slip ratio, the vertical load, the effects of tire heating produced by the skidding process, and the effects of contamination of the ground surface by abraded rudder. Some quantitative indications of these effects were obtained from the experimental data but the nature of the tests did not permit complete separation of all individual effects.

The investigation of the effects of wheel prerotation indicates that this means can be used to obtain appreciable reductions in the maximum drag loads; however, at very high forward speeds, because the spin-up drag loads may be of the same order as, or even less than, the drag loads caused by other design conditions, the practical advantages of prerotation could be greatly reduced.

From authors' summary

Thermodynamics

(See also Revs. 181, 190, 203, 209, 319, 324)

Book—270. Wilson, E. D., and Ries, H. C., Principles of chemical engineering thermodynamics, New York, McGraw-Hill Book Co., Inc., 1956, ix + 376 pp. $7.50.

Authors have succeeded where other authors of thermodynamics books have failed; namely, that thermodynamics is presented not as some monster to be feared and avoided, but rather a tool and method of approach to the solution of industrial problems. The influence of a combined 30 years industrial experience of the authors becomes markedly evident as one reads the book. However, this influence is not injected at the sacrifice of the fundamentals. The general theme is to first present the fundamental principles clearly and understandably; next, to introduce complications that make rigorous application of the principles impossible or extremely difficult in most cases, to introduce empirical approaches, and simplifications necessary to solve the problem, and finally, to present the actual methods of solution of practical industrial problems.

The student is made aware of the importance of the fundamental principles. At the same time, he is made aware of the shortcomings of the ideal solutions. There is one unique feature of the book which the reviewer particularly liked. This is in the presentation of the problems. All problems are concentrated in the appendix in one group. However, the uniqueness of the problem section is the initial presentation of a flow sheet for a hypothetical ethylene plant. The flow sheet shows the feed preparation for a cracking operation to produce ethylene, and also the actual cracking operation. From most of the chapters, problems are assigned that refer to this flow sheet, and are given special designations so that they may be easily picked out. Other problems are given which are not related to the flow sheet. As the student progresses, he sees how the work of the various sections are integrated. The importance of thermodynamics is made apparent from the large number of times it comes into use in the calculations in this comparatively simple unit. Each succeeding set of problems makes use of the results of the problems worked previously. Chemical engineering students should find a course following this particular text extremely interesting because of the stressing of the practical applications. It is quite evident throughout the book that the authors have a thorough understanding of the everyday problems of a chemical process plant designer.

The book is divided into fourteen chapters and four appendices. The first chapter is an introductory chapter discussing definitions of the terms used and discussion of units. This particular chapter is well written and should eliminate many of the problems that students in thermodynamics have because of an inadequate understanding of dimensions and units. The second chapter concerns the various states and properties of matter. The third chapter discusses the first law of thermodynamics in a rather clear, but not unusual, manner. The discussions and illustrations are quite similar to those found in many other books. The fourth chapter discusses the applications of the first law. Chapter five is concerned with the handling and compression of fluids. In this chapter a very brief discussion is given of the various types of pumps and compressors used for moving fluids. The main body is devoted to the calculations required for designing and specifying compressors. The chapter concludes with a good illustrative example of a typical problem which might be encountered in industry.

Chapter six contains a discussion of various thermochemical effects, including dissolution, enthalpy concentration diagrams, mixing, chemical reactions, heating of fuels, temperature effects on reactions, autothermic processes, and practical industrial chemical reactions, to illustrate the complicating factors which arise in industry. Chapter seven discusses the second law in a rather brief, and not unusual, manner. Chapter eight is concerned with graphical presentations and interpretation. In many books the graphical presentation and interpretation is neglected, and it is pleasant to see a separate chapter devoted to it. Included in this chapter are graphical solutions for various types of problems, such as graphical determination of heat capacities, or solutions of three simultaneous equations.

Chapter nine is devoted to the thermodynamics of steam-power plants. It is very short, and perhaps one of the weakest chapters in the book. Chapter ten discusses refrigeration, including a very brief treatment of heat pumps. Only the very simple refrigeration cycles are discussed. More complicated cases, such as two-stage cascade systems, etc., are not considered. Chapter eleven is devoted to a discussion of thermodynamic potential functions, including a discussion on the derivation of the various Maxwell relations. The chapter is concluded with a discussion of the physical significance of free energy and work. This latter portion is important because the usefulness of the concepts of free energy and work will be extremely limited unless the student has a sound understanding of their physical significance. It has been the reviewer's experience that the failings of many books and courses in thermodynamics are the lack of emphasis on the physical significance of some of the concepts used. A student can not be expected to solve practical problems if he does not have a feeling for the significance of such things as free energy, entropy, work, etc. Chapter twelve discusses the shortcomings of ideal gas laws and compares real gases with ideal gas laws. Van der Waal's equation, Beatte-Bridgeman equation, the Berthelot equation, etc., are all discussed.

Chapter thirteen concerns phase equilibria, including non-ideal solutions, real gas mixtures, vapor-liquid equilibria, hydrocarbon equilibria, etc. The van Laar and the Margules relations are presented and discussed.

Chapter fourteen concerns chemical equilibria, including discussion of the third law of thermodynamics. Also included are further discussions of free energy, fugacity and activity. In ad-

dition, estimation of free energies of formation from solubility data are presented. The chapter concludes with a discussion of a typical practical problem, namely, that of a heterogeneous reaction.

The four appendices include considerable thermodynamic data, calculation of frictional losses in various systems, estimation of free energy formation of solids from solubility data, and the homework problems.

Reviewer found the book very pleasant reading and is of the opinion that it should prove to be one of the better undergraduate chemical engineering texts. R. J. Mindak, USA

271. Buchner, E., and Strobel, R., On highly dissociated gases (in German), *Z. Flugwiss.* **5**, 2, 33–43, Feb. 1957.

Computation of composition, enthalpy, and entropy of dissociating gases is discussed. Method is presented in detail for diatomic gas; numerical results and graphs are given for hydrogen for temperatures 2000, 2500,.... 4000 K and pressures 1/16, 1 and 16 kg/cm². As example of a combustion gas, a mixture of 3.852 gram atoms hydrogen, 3.326 gram atoms oxygen, and one gram atom carbon is treated, assuming no free carbon (CO not dissociated at highest temperature, 4000 K). Results are given for temperatures 2000, 2500,.... 4000 K, and pressures 1/4096, 1/256, 1/16,.... 16,256 kg/cm². An approximate method due to C. Wagner is compared with exact computation for both examples. Its range of validity is established and it is found inadequate for highly dissociated gases. The isotherms in the enthalpy-entropy diagram are shown to have an inflection point for both systems.

Unfortunately, two references frequently cited throughout paper and required for full understanding are virtually inaccessible. One is as yet unpublished work by senior author, the other a "Peenemünder Archiv-Bericht" on Wagner's approximate method.

G. H. Markstein, USA

272. Kestin, J., and Wang, H. E., The viscosity of five gases: a re-evaluation, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–72, 7 pp.

273. Sanger-Bredt, I., Thermodynamics of working gases in atomic rockets, *J. Brit. interplanetary Soc.* **15**, 5, 233–248, Sept.-Oct. 1956.

274. Spencer, H. M., Temperature dependence of the heat capacity of gases, *J. chem. Phys.* **25**, 2, p. 357 (Letters to the editor), Aug. 1956.

275. Hirschfelder, J. O., Heat conductivity in polyatomic, electronically excited, or chemically reacting mixture. III, *Univ. Wis., Nav. Res. Lab.* CM-880, 40 pp., Aug. 1956.

A survey is made of the theoretical problems involved in estimating the heat conductivity in a chemically reacting gas or gas mixture. The new developments which have not been previously considered [See also AMR **10**, Revs. 291, 1222] are: (1) The larger the value of the entropy change in a chemical reaction, the larger is the maximum value of the specific heat of the reacting mixture and the coefficient of thermal conductivity of the reacting gas mixture. (2) The deviation of the chemical composition from the local equilibrium (or thermodynamics of irreversible processes) solution is expressed very simply in terms of the higher temperature derivatives. This deviation results in non-Fourier heat conductivity analogous to non-Newtonian viscosity. (3) The large Prandtl numbers of simple gases at very low temperature and polar gases at room temperature are supposed to be due to the distortion of the molecular distribution as the result of rotational-translational interactions. The Pradntl numbers for "rough" spheres and for rigid spheroids are found to be somewhat larger than would be expected on this account. (4) Although the Prandtl number of different substances is the same value to within a few percent, the Prandtl number for mixtures may be twice as large or one-half as small as the Prandtl number of its components. (5) An Eucken-type expression is derived for the coefficient of thermal conductivity of a polyatomic gas mixture and found to agree with experimental data. This formula involves the coefficients of self and ordinary diffusion for all of the molecular species.

From author's summary

276. Raman, C. V., The specific heats of some metallic elements, *Proc. Indian Acad. Sci.* **45**, 1. **Part I: Analysis of the experimental data,** 1–6, Jan. 1957 **Part II: Approximate theoretical evaluation,** 7–14, Jan. 1957.

277. Hufnagel, S., Investigation of the process in a steam reduction valve (in German), *Brennstoff-Warme-Kraft* **9**, 5, 233–238, May 1957.

Investigation relates to the process of lowering the steam temperature by injecting water into the throat of a reduction valve designed by Siemens-Schuckert. A brief review of thermodynamics of throttling is followed by description of instrumentation and test results. Method used in this investigation was optical determination of mist downstream of reduction valve throat. Maximum amount of water that can be fully vaporized, depending on the parameters of steam, is given. Article can be of interest to engineers dealing with process steam. J. J. Dziewonski, India

278. Willm, G., The accuracy of the thermodynamic method as seen after two years of industrial application (in French) *Houille blanche* **11**, 4, 608–618, Oct. 1956.

Author recapitulates the principles of the thermometrical method of measuring the efficiency of hydraulic turbines and describes equipment. Analytic study is made of the seven causes of error. Paper points out precautions to be taken when applying the method so as to maintain accuracy of measurements. Comparison is made of sources of error and the remedies for them in thermometrical measurements; author examines the absolute value of tests and their value when compared with classic methods and gives an account of various singular cases.

From author's summary

279. Duwez, P., Utilization of solar furnaces in high-temperature research, *Trans. ASME* **79**, 5, 1019–1023, July 1957.

This paper presents a theoretical discussion of the performance of a parabolic-type solar furnace. Maximum temperature and maximum heat flux attainable at the focus are presented for furnaces of different diameter-to-focal-length ratios. It is shown that the optical quality of the parabolic reflector is the most important factor for obtaining high heat fluxes. With present-day technology, the heat flux is limited to 600 Btu/sq ft/sec, but this figure could be raised to 2300 Btu/sq ft/sec by improving the optics.

From author's summary

280. Whillier, A., Solar energy, *South African Instn. mech. Engrs.* 2, 261–266, Mar. 1956.

281. Yellott, J. I., Power from solar energy, *Trans. ASME* **79**, 6, 1349–1359, Aug. 1957.

Following a brief historical introduction, paper points out the need for solar energy to supplement fossil fuels and nuclear power. The nature of solar radiation is described, and methods are given for estimating the amount available at any particular location. Flat-plate and concentrating collectors are discussed, and recent technical advances are reported, including selection surface coatings and new tube-in-sheet materials. Cycles and prime movers are considered. Need for water in vapor-cycle condensers indicates usefulness of hot-air engines. High thermal efficiency is advocated as a means for reducing fixed charges by cutting size of collectors and rejectors.

From author's summary

Heat and Mass Transfer

(See also Revs. 30, 32, 33, 66, 88, 96, 97, 108, 111, 175, 202, 203, 204, 206, 215, 216, 244, 270, 275, 279, 281, 313, 319, 322, 323, 350)

Book—282. Ruddle, R. W., The solidification of castings, London, The Institute of Metals, 1957, 406 pp. $6.50.

Foundry technology is an art into which science has been slow in penetrating, a field where mathematical approaches—even the elementary ones—have been used but sparingly. It is therefore refreshing to see the appearance of a well-founded book, treating in an authoritative manner the most important aspects of foundry teachnology, namely, those pertaining to solidification of castings. This well-documented exposition of the subject (there are more than 300 references) discusses: I. Experimental methods; II. The mechanism of solidification in castings; III. Mathematical treatment of solidification rates; IV. Heat extraction by moulds; V. Solidification rates in sand castings; VI. Solidification rates in ingot and chill castings; VII. The solidification of continuous castings; VIII. Application to the production of sound castings, and, in an Appendix, the thermal properties of metals and mould materials.

It is found that heat transfer plays a fundamental, frequently a dominant, role in solidification, and that the mathematical representation of the freezing ingot by a semiinfinite pure metal cast into a semiinfinite mould, where the properties of mould, the frozen and the liquid metal are temperature independent—one that is amenable to relatively simple mathematics—is frequently a reasonably good one. Several of the topics treated are of special interest to heat-transfer specialists. A discussion of the difference equation method of solution is given for problems involving a phase change, as used by Dusinberre for temperature-independent properties, and as used by Sarjant and Slack for the case of temperature-dependent properties. (The reader will also be impressed by the unattractiveness of analytical approaches to this type of problems as contrasted with "analog" methods.) Theoretical and semiempirical methods are presented to correct for corner effects and effects of curved surfaces. The "analog" method of Paschkis is explained, and is compared with available test data. (Other "analog" methods are also discussed, but not the "active analog circuit" methods.) W. Pellini's extensive tests, by which he determined the cooling curves of ingots (mostly steel) cast into iron or sand moulds, are discussed in detail; so are author's own experiments (mostly for nonferrous metals). A very extensive tabulation of mould material properties is given.

Reviewer has two minor complaints. One is that in the mathematical section, where method after method is discussed, the underlying assumptions are not clearly listed in each case. The other is that the author frequently does not define a foundry term, but assumes that the reader is familiar with it. However, the latter deficiency may be remedied by a quick perusal of the book "Metallurgy for engineers" (Wiley) by Wulff, Taylor and Shaler, who define all the important terms of foundry practice by means of excellent illustrations. A final impression after reading the book: One cannot help being impressed by the great progress made in the past ten years in understanding the solidification phenomenon. The next ten years will probably see an equally significant progress in the control of solidification.

G. Horvay, USA

283. Wilson, J. C., Heat transfer at rectangular corners, *Quart. appl. Math.* **15,** 2, 195–198, July 1957.

Author obtains the transient conductive heat-flow solution without internal sources for a rectangular corner of a solid, semiinfinite in two directions. The initial temperature is assumed zero, and the boundary conditions correspond to the temperature distribution approximated by a two-dimensional flame impinging on the corner. A solution containing the first five terms of the series is given. For appropriate values of time and space, the five-term series can be evaluated and the magnitude of the error involved can be calculated.

E. V. Somers, USA

284. Serizawa, Y., Some analysis of the temperature rise of trough-installed cable system, *Bull. Fac. Engng., Yokohama nat. Univ.* **6,** 63–74, Mar. 1957.

Paper describes characteristics of temperature rise of trough-installed cables and the experimental device for determining the thermal constants of the various elements in such an installation. A simplified, equivalent thermal circuit was used which was analyzed with the aid of usual electrical analog technique employing circuit consisting of lumped resistances and capacitances. Calculated results on temperature rise of the cable in its relation to electric load and exposure to sun's radiation were compared to measured data and were found to be in satisfactory agreement.

B. T. Chao, USA

285. Schneider, P. J., Temperatures and thermal stresses in transpiration-cooled power-producing plates and tubes, *Jet Propulsion* **27,** 8, pt. 1, 882–889, Aug. 1957.

Solutions are given for the local temperature, mean temperature, efficiency, surface temperature difference, and thermal stress in transpiration-cooled porous plates and tubes generating uniform distributed heat. Eight special cases are considered, four of which refer to the conventional case of nongenerating porous materials.

W. M. Rohsenow, USA

286. Lykoudis, P. S., and Touloukian, Y. S., Heat transfer in liquid metals, ASME-AIChE Heat Transf. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-16, 11 pp.

Steady-state heat transfer to liquid metals in a long pipe is semi-theoretically analyzed for turbulent flow and constant wall heat velocity. Analysis is simpler than Martinelli's in that a single velocity-distribution function, $u^+ = 3.4 \ln (y^+ - 1)$, is employed. The local radial heat velocity q/A is assumed proportional to the radius. The ratio σ of the turbulent thermal diffusivity to the momentum diffusivity is assumed <1 by the heat conducted away from the eddies during their travel, as in Deissler's theory. This yields σ as a power series of Prandtl number with a single assignable constant, which was determined from a selected experimental point in Johnson, Hartnett, and Clabaugh's study on Pb-Bi eutectic.

The temperature profile, average temperature, and Nusselt number are plotted, and agree well with above Pb-Bi data. This procedure yields tractable equations for temperature profile and Nusselt number for a liquid of zero Prandtl number. These equations are functions only of the von Karman number, and of the Prandtl number multiplied by σ.

C. F. Bonilla, USA

287. Cess, R. D., and Grosh, R. J., Heat transmission to fluids with low Prandtl numbers for flow through tube banks, ASME-AIChE Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-12, 5 pp.

This study is an extension of the same authors' analytical study of heat transfer from a cylinder to liquid metal flowing normal to the cylinder. In extending the work to tube banks it was further assumed that ϕ, the hydrodynamic potential per unit fluid velocity, on the surface of a tube in a bank increases from O at the forward stagnation point linearly with distance along the front-to-back diameter D to a value ϕ_1 at the rear stagnation point, also that there is no thermal effect of tubes in any one bank on those in the other banks.

The Nusselt number for an isothermal tube in a bank was shown to be that for an isolated tube, corrected by the factor $(\phi_1/2D)^{1/2}$. $\phi_1/2D$ for any given tube arrangement was empirically obtained by cutting electrically-conducting sheet to the outlines of the fluid in the bank and finding the relative voltage drops between the

forward and rear stagnation points at the same current density, for the bank and for a wide sheet with a single hole. A plot of the factor is given for both symmetrical directions of approach for square and for equilateral triangular banks, as a function of tube spacing-to-diameter ratio. Corrections for front and rear banks and for nonisothermal walls are given. The result agrees well with R. J. Hoe's low-velocity mercury data, but, as might be expected, falls somewhat below his high-velocity data, where eddy conductivity is more important. C. F. Bonilla, USA

288. Test, F. L., A study of heat transfer and pressure drop under conditions of laminar flow in the shell side of cross-baffled heat exchangers, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-3, 7 pp.

Paper discusses heat exchangers in which the oil-to-water flow is laminar and develops heat-transfer and pressure-drop correlations for an effective Reynolds number below 100. The principal variables considered are oil-weight rate, mean oil temperature, mean water temperature, and baffle spacing. It was found that an increase in baffle spacing increases the rate of heat transfer and decreases the pressure drop, particularly at low oil flows. The oil-film coefficient changes very rapidly with mean water temperature. The heat-transfer and pressure-drop results are correlated on the basis of an effective Reynolds number. The effective Reynolds number is a junction of the effective area accounting for various leakage passages. The correlations predict results that rarely differ by more than 10% from the experimental results.

From author's summary by G. G. Thurlow, England

289. Burr, A. H., and Dropkin, D., The prediction of journal-bearing temperatures by the application of heat-transfer theory and data, ASME Semiann. Meet, San Francisco, Calif., June 1957. Pap. 57-SA-89, 18 pp.

Authors show how the title problem can be solved when all possible ways of dissipating the heat generated in the oil film are taken into account simultaneously. They even account for the heat carried away through the rotation convection, caused by the windage at the shaft surface outside the bearing, and show that in many cases this convection is far from negligible. Their theory is corroborated by measurements, under a variety of operating conditions, of bearing temperatures in the steady state.

H. Blok, Holland

290. Hoe, R. J., Dropkin, D., and Dwyer, O. E., Heat-transfer rates to crossflowing mercury in a staggered tube bank-I, *Trans. ASME* **79,** 4, 899-907, May 1957.

An experimental study is made of cross-flow heat-transfer coefficients for mercury flowing normal to a staggered tube bank for a Reynolds number range of 15,000-83,000 and Prandtl number value of 0.022. Particular attention is given to the effects of tube location, to the type of fluid contact (wet or non-wet), and to the circumferential variation of the local coefficient of a single tube. The most significant results distinguishing this metallic fluid behavior from nonmetallic fluids are a variation in heat-transfer coefficient for non-wetted tubes according to the 0.52 power of Reynolds number (0.60 for nonmetallic fluids) and a four- or five-fold circumferential variation in the local coefficient of a single tube (approximately twofold for nonmetallic fluids).

P. Chiarulli, USA

291. Smith, F. B., The diffusion of smoke from a continuous elevated point-source into a turbulent atmosphere, *J. fluid Mech.* **2,** 1, 49-76, Jan. 1957.

Downwind concentration of nonbuoyant smoke (or air pollutants) is determined analytically. Eddy diffusivity coefficients and velocity are represented by related powers of distance from ground and are taken independent of source position. For one special value of the velocity profile parameter, α, (for which value of α the mathematics is least complicated) concentrations are determined exactly, and it is found that the cross-wind distribution has a Gaussian form. Assuming that the cross-wind profile is Gaussian for all values of α, calculations are made then for several other values of α. Graphs presenting, as a function of distance downstream from source, concentrations at ground level for five values of α and at three heights for one special value of α are included. Author provides excellent physical description of problem and results in spite of occurrence of numerous special mathematical functions. E. L. Knuth, USA

292. Andrews, S. J., and Bradley, P. C., Heat transfer to turbine blades, *Aero. Res. Counc. Lond. curr. Pap.* 294, 12 pp. + 11 fig., 1957.

An investigation of heat-transfer coefficients to cooled turbine blades of the nozzle and impulse type. Authors state that if the flow on a blade is laminar (first-stage nozzles and high reaction blades), the over-all Nusselt number can be calculated fairly accurately by a method due to H. B. Squire [*R. & M.* 1986, Nov. 1942] developed for flat plates and cylinders. For turbulent flow the results do not deviate too much from a common line, but no reliable method of calculation is still available. Authors obtained best correlation of experimental points with thermal conductivity and viscosity based on blade temperature and density based on the mean of inlet and outlet static pressure and mean of blade and stagnation temperature of the gas.

F. Krupka, Czechoslovakia

293. Chambre, P. L., The laminar boundary layer with distributed heat sources or sinks, *Appl. sci. Res.* (*A*) **6,** 5/6, 393-401, 1957.

The laminar thermal boundary layer with distributed heat sources or sinks over a flat plate is studied. A method for reducing the problem to an infinite system of ordinary differential equations is outlined for a general spatial distribution of sources or sinks. The specific case where the sources or sinks are uniformly distributed normal to the surface and vary in a prescribed manner along the flow direction is treated in detail. It is then pointed out that the equation and boundary conditions are identical to those obtained for a certain class of three-dimensional boundary-layer flows. The existing numerical solution of the latter problem corresponds to a solution of the considered problem for the case of Prandtl number equal to unity and when the free-stream temperature is representable by a polynomial of degree less than eleven. Pronounced effects on the temperature distribution due to the heat sources or sinks are indicated. S. Ostrach, USA

294. Masson, D. J., and Gazley, C., Surface-protection and cooling systems for high-speed flight, *Aero. Engng. Rev.* **15,** 11, 46-55, Nov. 1956.

Paper discusses systems for surface protection against transient and continuous heat inputs, corresponding to typical missile and aircraft flight paths. Comparisons of various systems are made for several typical operating conditions.

From authors' summary

295. Gazley, C., Jr., Heat-transfer characteristics of the rotational and axial flow between concentric cylinders, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-128, 16 pp.

Paper considers the convective heat-transfer characteristics of the flow in the annular gap between a rotating inner cylinder and a stationary outer cylinder. Heat-transfer measurements are reported for two gap sizes and various combinations of axial and rotational flows. Both smooth and slotted surfaces were used. Measurements for laminar and turbulent-flow conditions followed the trends predicted by theory. An unusual feature of the results for rotational flow without axial flow is the heat-transfer rate in an intermediate flow region existing between the laminar and turbulent

regimes. Here, regular ring-shaped vortices cause a heat-transfer rate even greater than with turbulent flow.

From author's summary

296. Zernik, W., The dust-free space surrounding hot bodies, *Brit. J. appl. Phys.* **8,** 3, 117–120, Mar. 1957.

A quantitative theory is advanced to explain the dust-free space around hot bodies. The radiometer force, derived by Epstein, is equated to the aerodynamic force, derived by Stokes. In the calculation of the latter, the velocity in Stokes' law is taken to be the velocity of air normal to the hot surface, which has been given by Schmidt and Beckmann in the case of vertical plate and by Hermann in the case of horizontal cylinders. When the theoretical results are compared with Watson's experimental data, it is found that, though the validity of the theory is based on that of the boundary-layer equations and the experimental data were obtained at Grashof numbers too low for the boundary-layer equations to be valid, the agreement is nevertheless good for vertical plates and sufficiently good to show the correct order of magnitude and the correct trend in the case of horizontal cylinders.

Reviewer finds paper interesting. C. S. Yih, USA

297. Morton, B. R., Buoyant plumes in a moist atmosphere, *J. fluid Mech.* **2,** 2, 127–144, Mar. 1957.

Transport of water vapor by thermal plumes is investigated analytically assuming that vertical velocity, temperature, and specific humidity are constant across ascending column, and that inflow velocity due to mixing at edge of plume is proportional to vertical velocity within plume. Starting with the conservation equations for mass, momentum, energy, and water vapor, exact solutions are obtained for a neutrally stable atmosphere and numerical solutions for a stable atmosphere. It is shown that the plume air becomes saturated, and clouds are formed, if the source is sufficiently strong. For a stable atmosphere, the analysis is continued for heights above the saturation level, taking into account both liquid and vapor phases of water.

E. L. Knuth, USA

298. Chang, Y. P., A theoretical analysis of heat transfer in natural convection and in boiling, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-42, 9 pp.

Paper presents a stimulating different approach to the problem of boiling heat transfer. However, there are apparently a number of errors in the natural-convection portion of the paper. For example, author essentially analyzes a thermally unstable flow, but neglects those terms in his analysis which describe the instability. This point is discussed in more detail by Tribus and Zuber in comments which will be published with the paper in the *Trans. ASME.* In spite of other inconsistencies, which Tribus and Zuber also note, a number of provocative ideas are presented in this paper. S. Ostrach, USA

299. Grant, W. L., The determination of the heat transfer coefficients of flat surfaces, C. S. I. R., Repr. EASA, 27 pp., Dec. 1955, Mar. 1956, June 1956,

The determination of the film coefficient for the convection of heat from a flat plate is first studied theoretically. For laminar flow the exact solution can be found by analytical methods under suitable simplifying assumptions; for turbulent flow the analogy between fluid friction and heat transfer is used, along with some semi-empirical methods. The cases treated are: laminar flow with forced or natural convection and turbulent flow with forced convection. The analysis shows that the local film coefficient can be calculated from the distance y between the surface and the point at which the temperature increment is some specified fraction of the total temperature difference between the wall and the free airstream; this suggests a technique for the direct determination of the local film coefficient, viz. to measure y. To check this experimentally, a heater plate was constructed, the details of which are presented. Testing is still in progress; from the preliminary test results which are presented, it appears that further work will be required to validate the method.

H. D. Block, USA

300. Zuber, N., On the stability of boiling heat transfer, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-4, 4 pp.

Author proposes a mechanism for the transition from nucleate boiling to film boiling and from film to nucleate based on the stability of the liquid-vapor interface. From first principles, the burnout, or maximum heat flux, is related to the fluid properties for saturated pool boiling. The agreement with the data is excellent. Author also predicts the heat flux at the transition from film to nucleate boiling (the minimum or the q/A versus ΔT curve) for one particular case. Transition heat fluxes are found to be insensitive to surface conditions.

The work represents a real advance in the knowledge of burnout process and removes the uncertainty regarding the true limiting process under most circumstances.

P. Griffith, USA

301. Kern, D. Q., Horizontal condenser theory I. Mathematical development of tube loading, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-28, 16 pp.

Although the Nusselt theory has been found invalid for a vertical bank of tubes, it remains the basis for designing horizontal condensers containing a multiplicity of such banks. Equations for condensate loading are derived from the common tube layouts bounded by a circle. These equations indicate that the average value of the condensing coefficient should vary with the size and type of pitch and that a condition of ideal layout exists which differs from present design practice.

Paper, especially when completed by second part, should enable much more precise designs of orthodox—filmwise condensing—condensers to be produced.

From author's summary by G. G. Thurlow, England

302. Graham, R. D., Effect of several drying conditions on strength of coast-type Douglas fir timbers, *Forest Prod. J.* **7,** 7, 228–233, July 1957.

The effects were investigated of various temperatures during air-drying, kiln-drying, and organic-vapor-drying on drying rate, hygroscopicity, checking, and strength of 4-in. × 8-in. × 10-ft. heartwood coast-type No. 1 Douglas fir. Strength tests were performed on full-size beams and small specimens cut from the timbers.

The strength properties were reduced 15% and more by the high kiln-drying temperatures of 200 F instead of the customary 150 F. Air-dried timbers were approximately 40% stronger in flexure than the green counterparts. High drying temperatures apparently decreased the hygroscopicity of the wood; however, also decreased by one-half the time required to reduce the moisture content to 16%. E. G. Stern, USA

303. Gorling, P., Investigations into the behavior of vegetable substances during drying (in German), *VDI-Forschungs-heft* **22,** 458, 35 pp., 1956.

This investigation deals with the phenomena occuring during the drying of vegatable substances with the object of supplying sufficient information for the prediction of drying processes under any chosen conditions. Interpretations of extended measurements on the sorption properties of potatoes and of timber revealed that, with increasing moisture content, at first monomolecular and then polymolecular water binding can be assumed. Finally, water binding sets in due to capillary condensation as could be established experimentally for potatoes. The evaluation of a large number of

drying-rate curves obtained at various temperatures for potato samples confirmed earlier results according to which the moisture transfer is caused by the combined influence of capillary moisture transfer and vapor diffusion as in the case of nonhygroscopic porous materials. It was thus possible to explain the drying-rate curves consisting of three periods and to determine the relations governing the critical points which separate these periods. As properties responsible for the capillary transfer and vapor diffusion in potatoes, the moisture conductivity and the relative diffusional resistance, respectively, were calculated using the measured moisture distributions and the drying-rate curves. Both quantities exhibited the same peculiar dependency on the moisture content as in wood in accordance with the capillary conditions in vegetable substances. From author's summary

304. Jacket, H. S., Roarty, J. D., and Zerbe, J. E., Investigation of burnout heat flux in rectangular channels at 2000 psia, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-6, 10 pp.

Burnout heat-flux data were obtained under conditions of approximately zero exit quality and bulk boiling at the exit of electrically heated test specimens. These specimens were long, narrow channels with various slot thicknesses, surfaces, materials, and length-to-diameter ratios. Tests were run at 2000 psia and mass velocities from approximately 0.2×10^6 to 3×10^6 lb/hr-sq ft. The effect of inclining the channel at 45 deg also was investigated. The rectangular channel burnout results are in reasonable agreement with data previously obtained for round tubes. A design equation is suggested which yields a conservative estimate of the burnout heat flux in the low subcooling and quality regions for the range of variables investigated herein. A burnout loop and method of operation are described. P. Griffith, USA

305. McEwen, L. H., Batch, J. M., Foley, D. J., and Kreiter, M. R., Transfer "beyond burnout," ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-49, 6 pp.

The q/A versus ΔT curve for water at 1500 psia boiling in a horizontal thick wall tube at heat fluxes of 100 to 396 thousand Btu/hr-ft^2 is presented for various mass velocities. Considerable stratification is found to occur so that the top of the tube can be "burned out," while the bottom is still in nucleate boiling. This occurs without physical burnout to the tube. The net result is there is no minimun in the q/A versus ΔT curve for some of the runs. P. Griffith, USA

306. Hsu, Y. Y., and Westwater, J. W., Film boiling from vertical tubes, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-24, 8 pp.

Measurements were made of film coefficients for the film boiling of various organic fluids for a vertical tubular heater in pool of the saturated fluid. No stable laminar film appeared to exist for a heater oriented in this manner. The measured film coefficients were of the same order but higher than those given by a Bromley-type equation for stable film boiling. A correlation is presented which fits all but the data for methanol.

P. Griffith, USA

307. Juhasz, S., and Levy, S., Generalized crossflow heat exchange with parallel flow, counter flow, and cross-flow as special cases, *Medd. Varmestromsgruppen* 3, 0-7, 1957.

Vector analysis is used to develop an energy balance equation for steady-state heat transfer between two fluids which flow in adjacent parallel passages. The fluid flow vectors make an arbitrary angle B with each other. For $B = 0$, 90, and 180 degrees, the equation reduces to known equations for parallel, cross, and counter flow. Results may be applied to entrance and end section of heat exchangers where fluid flow angles are variable.

J. L. Mason, USA

308. Fairall, R. S., A new method of heat-exchanger design with specified inlet and outlet conditions, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-5, 10 pp.

In order to solve the general design problem for a heat exchanger, the relative advantages of a number of possible solutions must be compared with the respective disadvantages. The solutions may be compared on a basis of flows, pressure losses, temperatures, and heat-exchanger size and weight. Paper develops a set of simultaneous equations which expresses the size of a heat exchanger as a function of the operating conditions and the surface temperatures within the unit and permits this comparison to be made on an analytical basis. The general case of counterflow, parallel flow, single-pass crossflow and two-pass crossflow are solved; examples and figures are included. The development of high-speed computers makes methods such as this practical propositions, and the paper is of practical importance.

From author's summary by G. G. Thurlow, England

309. Chibaeff, V. G., Multitubular heat exchangers of minimum weight (in French), *Rev. Inst. fr. Petrole et Ann. Comb. liq.* **11,** 7/8, 961-971, July/Aug. 1956.

The weight of the stainless steel parts of a stainless-steel exchanger (tubes, tubular plates and shell) as well as the total weight of a carbon-steel exchanger are a function of tube length. This function presents a minimum value for a determined length. Author assumes the heat-transfer coefficient to be constant, and determines corresponding optimum length for stainless-steel and carbon-steel exchangers. C. Codegone, Italy

310. van Spiegel, E., Method of calculation for heat-regenerators of blowdown wind tunnels, *Nat. LuchtLab. Amsterdam TM* F. 190, 14 pp. + 4 figs. 1956.

Nonsteady operation of an idealized one-dimensional regenerator is treated by solving the resulting hyperbolical-type differential equation by the Riemann method (exact solution) and, alternatively, by using a finite difference (approximate) method. The latter is applied to two examples which also serve as illustrations for the usefulness of both apparatus and method of calculation.

H. H. Korst, USA

311. Lambertson, T. J., Performance factors of a periodic-flow heat exchanger, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-13, 7 pp.

Various attempts have been made to calculate the performance of the periodic-flow (rotary-regenerator-type) heat exchanger. Author has now developed a numerical finite-difference method of calculation, considering the metal as a crossflow "stream" with each of the gas streams, the whole being viewed as two separate but dependent exchangers. The use of a general-purpose digital computer enables the method to be used to calculate accurately the effectiveness of the exchanger over wide ranges of the following parameters: capacity-rate ratio of fluid flow streams, capacity-rate ratio of rotor matrix to minimum fluid-capacity rate, the overall number of transfer units (N.T.U.), and the symmetry of the exchanger (i.e. the ratio of (bA) on each side of the exchanger where b is unit convective conductance, A heat transfer area).

Results agree with but generalize the earlier, but more restricted, analyses. G. G. Thurlow, England

Combustion

(See also Revs. 174, 270, 271, 283)

312. Bair, W. E., Olson, D. R., and Lichty, L. C., Spontaneous ignition of n-heptane-air mixtures in a steady-flow process, *Indust. Engng. Chem.* **49,** 4, 774-779, Apr. 1957.

Pre-mixed fuel-air was "burned" with cold flame in a heated 1-in. pipe, 11.5 ft long. Energy release resulted in gradual increase in pipe wall temperature until spontaneous ignition occurred—a matter of 20 minutes for experiment described. Practically all of energy liberated before spontaneous ignition occurs took place in first 2 ft of the reaction tube. Energy liberated increased with time from about 2000 Btu/lb of fuel to about 4000 Btu/lb of fuel. With increasing air-fuel ratio above stoichiometric, energy release per lb of fuel increased. Flow in the reaction tube was held in turbulent region, N_{Re} above 4000.

Authors recognize that spontaneous ignition tests depend greatly on the kind of apparatus used, yet they could only shift the range of limitations. The tests permitted them to study heat transfer and energy liberation prior to spontaneous ignition. However, no other size or design of apparatus was employed to indicate relative significance of apparatus compared to inherent combustion phenomena. D. Aronson, USA

313. Ghosh, B., and Orning, A. A., Igniting pulverized coal, *Indust. Engng. Chem.* **47,** 1, 117–121, 1955.

Paper is a study of influence of certain factors upon the ignition process, independent of the influence of the same factors on the resulting flame. Factors investigated are coal characteristics, fineness of grinding, distribution of coal in the air stream, heat loss from the flame, and aerodynamic factors. The interaction of these factors is not well understood, because of the opposing influences upon energy release in the flame, and upon energy transfer processes which produce the ignition of the coal. The understanding of these influences is a prerequisite for the rational design of coal burners. Small flames were produced in an electrically heated furnace, so that most of the heat of ignition came from the furnace at an independently controlled temperature rather than from the flame. The apparatus consisted of an electrically heated furnace, 4 × 4 × 1.5-in. volume, and a constantly recirculated air in which the powdered coal was kept in suspension. Results are presented mostly in charts, as (1) ignition time versus coal concentration at various furnace temperatures, varying between 900 and 1200C; (2) ignition time versus coal concentration at various fineness of powdered coal; (3) effect of sonic energy upon ignition time; (4) effect of oxygen enrichment on ignition time. The theoretical analyses of Nusselt and of Traustel, which consider the heat transfer to the coal by radiation, and heat loss by conduction, are briefly discussed.

K. J. DeJuhasz, Germany

314. Troshin, Ya. K., Generalization of Huygens' equations for nonsteady processes of flame propagation in pipes (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **103,** 3, 465–468, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5047.

Study of propagation of an explosion consisting of a shock wave and a zone of combustion following it, for the case when the region between the shock wave and the zone of combustion continually increase.

An equation was obtained which gave the connection between the pressure p_1 and the density ρ_1 behind the explosion and the relationship of the gas pressure $\mu = p_1/p_1$ up to and after the shock wave. For various boundary conditions this relationship gives the possibility of plotting curves on the $p - v$ diagram which completely describe the real conditions of flame propagation in pipes and, as opposed to Huygen's adiabatics, have neither prohibited nor imaginary sections. V. I. Yagodkin, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

315. Rapporneau, J., and Grassin, H., Flames stabilized by baffles—thermochemical structure of the stabilization core (in French), *Rech. aêro.* no. 58, 17–22, May-June 1957.

The recirculation zone behind a 25-mm disk baffle in a kerosene air stream at up to 150-mps velocity is made visible by the injection of minute amounts of fuel in the form of droplets, which burn with a yellow flame and so act as tracers. A watercooled probe was used to sample the gas at 79 points in this zone and obtain combustion efficiency by gas analysis. Experiments at rich and lean air-fuel ratios show very high turbulence within the core, and a combustion efficiency substantially equal to 1 throughout, confirming Mestre's view that the core consists of burnt gas in chemical equilibrium. A. G. Cattaneo, USA

316. Schramm, K. H., Theory of stationary flames in flowing gases (in German), *Dtsch. Versuchsanstalt Luftfahrt E. V. Rep.* no. 31, 22 pp., Apr. 1957.

The burning zone and flame front are studied for flammable fractionless ideal gas. This is studied for constant velocity and temperature of unburned gases. Differential equations are established and solved for the calculation of entropy along the flame front. The solution is formulated in terms of numerical integration which, in a practical case, may be carried out on an electronic computer.

These methods seem timely in view of the increasing use of electronic computers, and as iterative programs for the solution of such problems are becoming increasingly available.

J. H. Davidson, USA

317. Fine, B., Further experiments on the stability of laminar and turbulent hydrogen-air flames at reduced pressures, *NACA TN* 3977, 31 pp., Apr. 1957.

Work is continuation of AMR **10,** Rev. 2312, using same equipment and techniques. Author's summary of results: (1) The pressure exponent for the critical flashback boundary velocity gradient was the same for both laminar and turbulent flames. The composition at which it peaked was also the same. (2) The turbulent-to-laminar ratio of critical flashback boundary velocity gradients was 2.8. The difference between the gradients was not caused by an increased burning velocity for the turbulent case, but rather implied that the penetration distance for turbulent flashback was about 1/3 of the penetration distance for the laminar case. (3) Turbulent blowoff velocity was nearly independent of pressure and varied approximately with the inverse square root of burner diameter. None of the current mechanisms of flame blowoff predict these results. (4) Extrapolation of stability loops to the quenching point showed that the quenching pressure was inversely proportional to burner diameter. The actual pressures obtained were higher than those obtained by other methods.

D. Aronson, USA

318. Kurz, P. F., Stability limits of flames of ternary hydrocarbon mixtures, *Combustion and Flame* **1,** 1, 3–13, Mar. 1957.

Experimental studies of lean blow-off and flash-back limits of laminar flames of ternary hydrocarbon mixtures containing ethylene show that these stability limits of the mixtures are predictable. The fuel components are non-interfering in flames at these limits. The contributions of the individual hydrocarbons are additive and define the limit of the mixture. However, at rich blow-off, there is evidence of inhibition in mixtures where ethylene is the primary fuel and in mixtures where the ethylene concentration exceeds a certain minimum as a secondary fuel. Consequently, the rich blowoff limits of mixtures containing ethylene are not usually predictable. From author's summary by R. Cornog, USA

319. Lafon, R., An analog computer for evaluating the temperature of rocket flames (in French), *Rech. aêro.* no. 57, 23–29, Mar.–Apr. 1957.

A computer is described that is used in conjunction with color reversal equipment for measuring rocket flame temperatures. Two

signals, one originating from the flame alone and another originating from a filament lamp with the flame interposed, are fed into the computer. A third known signal is that from the lamp alone and may be obtained in the second channel by removal of the rocket flame. These measurements are converted into an absorption coefficient and consequently into a temperature by means of circuitry (diode networks) in the analog computer. The electronic details are explained very fully.

Reviewer believes that this device will save many hours of data reduction and that it provides a useful direct temperature reading in the temperature range beyond the reach of thermocouples, where none has been available hitherto. B. P. Mullins, England

320. Mickelsen, W. R., Effect of standing transverse acoustic oscillations on fuel-oxidant mixing in cylindrical combustion chambers, *NACA TN* 3983, 49 pp., May 1957.

Results of a previous study [AMR **10,** Rev. 1264] of the effects of transverse acoustic oscillations on diffusion from wakes from point sources are extended to explain some cases of screech in combustors. Acoustic oscillations of the magnitude present in screeching combustors can result in considerable transverse motion in and distortion of the fuel jets. Such transverse oscillations were found to (a) decrease the instantaneous concentration at nodes in the wake by a stretching of the length of wake, and (b) spread out the time mean concentration between nodes because of the back and forth fluctuation of the wake. Thus, for afterburners or ramjets, the flag-like motion of the jets can cause periodic out-of-phase fluctuations of fuel concentration on opposite sides of flame holder bars if these bars are not at jet nodes. This can lead to periodic local increases of heat release rate in phase with the pressure, and driving of the oscillation.

A second mechanism of producing oscillations also results from the periodic changes in concentration at other than the nodal positions. However, in this case, attention is focused on fuel-air ratio. For fuel lean mixture, increase in concentration occurs in phase with increases in pressure, and leads to an increased heat release rate. This results in driving of the oscillation. Conversely, fuel rich mixture tends to suppress this type of oscillation. Methods are suggested for suppressing combustion-driven oscillation resulting from fluctuations in fuel-oxidant ratio induced in the manner indicated above. A. A. Putnam, USA

321. Markstein, G. H., Flow disturbances induced near a slightly wavy contact surface, or flame front, traversed by a shock wave, *J. aero. Sci.* **24,** 3, 238–239 (Readers' Forum), Mar. 1957.

Book—322. Zinzen, A. Textbook on steam-boiler design and calculation [Dampfkessel und Feuerungen Lehr- und Handbuch], 2nd ed., Berlin, Springer-Verlag, 1957, ix + 289 pp. + 52 tables. DM 43.50.

This well-known textbook on steam-boiler design and calculation appears in a second revised edition after a period of lively development toward larger boiler units and new types of slagging furnaces. The book deals with every aspect of boiler design in a short but very instructive way. Although based mainly on the design of German manufacturers it is a valuable contribution in this special field. The problem of deposit formation—mainly based on the author's own studies and his ternary system, the "Zinzen" diagram—may require a broader treatment in the future since the number of mineral fuel constituents prohibits their enforcement into a ternary system. The book is highly recommended for teaching and self-instruction.

W. Gumz, Germany

323. Khitrina, L. N., and Goldenberg, S. A., Combustion of gas mixtures in a flow heated by a body (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **103,** 2, 277–280, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5048.

From the critical condition of combustion a relationship is derived from which it is possible to find, with the aid of certain test data, the values of the basic kinetic characteristics of fuel mixtures; in particular, the activation energy.

From the relationship obtained by the authors the presence of the concentration limits of combustion (flame propagation) are found and consequently the possibility of their treatment from the point of view of pure heat theory. G. I. Pokrovskii, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

324. Staab, F., Processes in pulse jet engines (in German), *Z. Flugwiss.* **5,** 3, 77–87, Mar. 1957.

Internal processes in pulse-jet engine are observed by means of pressure transducer records and streak flame photographs taken on a rotating drum camera. Discussion of results emphasizes combustion characteristics and includes a resumé of recent advances made in the design of pulse-jet engines.

A. K. Oppenheim, USA

325. Mayorcas, R., and Riviere, M., Description of trials and results, *J. Inst. Fuel* **26,** 211–224, 1953.

Details are given of the design and planning of the trials and the techniques of measurements on the flames from several commercial high-pressure blast-type burners, together with tables of the input variables, and graphs showing the effects of variables on several parameters such as radiation and emissivity of the flames and the temperatures of the surrounding walls. Results show that the greatest change of flame condition is brought about by a change in momentum of any given fuel quantity. Comparing flames from the same type burner, with the same momentum and fuel quantity, but with air as the atomizing and carrying medium in one case and with steam in the other case, the flame with air has a higher peak radiation and emissivity, but beyond this the two flames are indistinguishable. Increasing the momentum decreased the radiation and emissivity all along the flame length; the air-atomized flame was hotter than the steam-atomized flame. For the range examined, the size of oil droplets has no influence on the rate of combustion and subsequent emissivity and flame temperature. The biggest difference in mean particle size was produced by going from a back-end to a front-end mixer burner, and there was very little difference in their performance with regard to the combustion and radiation, and in efficiency of production of jet thrust for a given atomizing-agent-fuel ratio used between these two kinds of burner. Experiments and results are described in detail and illustrated by numerous flame photos, graphs, and tables. K. J. DeJuhasz, Germany

326. Putnam, A. A., Benington, F., Einbinder, H., Hazard, H. R., Kettello, J. D., Levy, A., Miesse, C. C., Pilcher, J. M., Thomas, R. E., Weller, A. E., Landry, B., Injection and combustion of liquid fuels, *WADC Tech. Rep.* 56-344, xxxii + 723 pp., 51 tables, 240 figs., 1100 ref.

This is a monumental monograph on the subject stated in the title, a work of many scientists, experts in their field, produced under the sponsorship of the United States Air Force, by the Battelle Memorial Institute. It is a critical review of unclassified literature relating to the physical phenomena involved in steady-flow process in high-intensity combustors. Intermittent sprays and their combustion, as in diesel engines, are not considered. For systematic treatment the subject is divided into six parts, subdivided into 19 chapters, under the following headings:

Part I. Atomization of liquid fuels:
- Chap. 1, The mechanism of atomization
- Chap. 2, Methods of atomization
- Chap. 3, Design of atomizers
- Chap. 4, Spray analysis

Part II. Ballistics of droplets:
Chap. 5, Ballistics of a single droplet
Chap. 6, Dynamics of dispersion
Part III. Evaporation of droplets:
Chap. 7, Thermodynamics and kinetics of evaporation
Chap. 8, Single droplet evaporation
Chap. 9, Evaporation of a moving droplet
Chap. 10, Spray evaporation
Part IV. Fluid Dynamics:
Chap. 11, Equations of fluid dynamics
Chap. 12, Turbulence
Chap. 13, Hydrodynamic recirculation
Part V. Homogeneous Combustion:
Chap. 14, Laminar flame propagation
Chap. 15, Turbulent flames of premixed gases
Chap. 16, Stability limits of premixed flames
Chap. 17, Ignition of combustible mixtures
Part VI. Heterogeneous Combustion:
Chap. 18, Droplet combustion
Chap. 19, Diffusion flames

Each chapter is preceded by an abstract; this is followed by a list and summaries of the work of previous investigators, given in sufficient detail to dispense with the original papers. Then a critical summary is given, and the significant references and bibliographic data are listed. The Institute and the contributors have given their unstinted efforts to make this volume complete and up to date, rendering thereby a great service to workers in this field. K. J. DeJuhasz, Germany

327. Macauley, R. W., and Gardiner, G. M., Increased life for gas turbine combustion systems burning residual fuels, ASME 1956 Gas Turbine Power Conference. Pap. 56-GTP-11, 7 pp. + 7 fig. + 2 tabs.

Authors describe combustion system of General Electric gas turbines, comprising combustion chambers and fuel nozzles. These two elements must be designed to work together. The nozzle comprises a set of fuel orifices, a supply of primary swirl air serving to spread the fuel evenly within the nozzle throat, and a supply of atomizing air introduced near the exit in a narrow annular slot. This atomizes the fuel and forms a relatively narrow spray having approximately a 60 deg included angle. By virtue of the comparatively large fuel orifices, a freedom from clogging is attained. The main operating conditions are as follows:

Combustion chamber pressure, 50 to 75 psig;
Maximum fuel flow, 800 lb/hr;
Maximum fuel viscosity, 20 centistokes; max temp. 250 F;
Maximum atomizing air flow, 700 lb/hr;
Maximum atomizing air pressure ratio, 2.0;
Minimum " " " " 1.5

Drawings of details of combustion chamber and of the nozzle are given. K. J. DeJuhasz, Germany

328. Batchelder, G. W., and Elder, J. K., A more explicit notation for the temperature sensitivity coefficients of solid rocket propellants, *Jet Propulsion* **27,** 5, p. 546, May 1957.

329. Arthur, J. R., and Smith, W. D., The size of solid fuel in relation to the behavior of combustion and gasification appliances, *Brit. Coal Utilisat. Res. Assn. Bull.* **20,** 11, 429-444, Nov. 1956.

330. Palmer, K. N., Smouldering combustion in dusts and fibrous materials, *Combustion and Flame* **1,** 2, 129-154, June 1957.

Smouldering rates of trains of cork dusts, beech and deal sawdusts, grass dust, and strips of fiberboard were measured under various conditions; data should be useful in prevention or investigation of industrial or storage fires. Smouldering, initiated by a small flame, generally proceded at 1 to 2 cm/sec in still air. For parallel air flow, smouldering rate increased with the 0.4 to 0.5 power of air velocity for fine cork dust and fiberboard and with the 0.8 power for grass dust. Effect of air velocity was much smaller for opposing flow. For coarse dusts in drafts, or for fiberboard which had been smouldering in still air and was then exposed to a draft, flaming could develop. Smouldering rates for fine dusts varied inversely with depth of dust layer, provided that the depth exceeded a critical minimum (order of 1 cm for still air), which in turn decreased with decreased particle size or increased air velocity. For deep dust deposits, the time of propagation from base to top was approximately proportional to the square of the depth. G. L. Dugger, USA

331. Nokhratyan, K. A., Aerodynamic calculation of furnace "charge" (in Russian), *Sb. tr. Resp. n.-i. in-ta mestynkh stroit. materialov* no. 9, 3-24, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5156.

The aerodynamic resistance of channels of various design with solid walls was determined, as well as the resistance of channels with cascade walls (1, 2, and 3 series) with a thick and thin cascade.

The value of the resistance referred to a meter length of the canal, at a flow velocity of 1 m/sec and temperature 0° of the channels with dense solid walls, was found to be within the limits of 0.008 and 0.3, and for channels with cascade walls it was found to be between 0.0135 and 0.075. The minimum resistance is afforded by channels with upper and lower cascade surfaces with a closely-spaced cascade, and the maximum resistance is given by channels with upper and lower cascade surfaces, but with a wide-pitch cascade.

Paper also examines problem of the local resistance of discontinuities (in the case of an abrupt variation in the section of the channel in the charge). On the basis of the results of experimental investigation of the aerodynamic resistance of charges of simple type the author has developed a method for calculating the resistance of a complex charge.

A comparison is given of the values of the aerodynamic resistance of five types of charge of an annular furnace and seven types of tunnel furnace, which were obtained by model tests and by calculation.

The comparison shows the calculation to have a satisfactory accuracy.

An experimental investigation was made on the ROSNIIMS aerodynamic plant in models of annular and tunnel furnaces of the resistance of a charge of solid and hollow standard brick and of hollow blocks in a range of speeds between 3 and 15 m/secs.
Courtesy Referativnyi Zhurnal I. I. Eskin, USSR
Translation, courtesy Ministry of Supply, England

Acoustics

(See also Revs. 32, 134, 135, 152, 264, 320)

332. Ram, G. S., and Ribner, H. S., The sound generated by interaction of a single vortex with a shock wave, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 1-22.

The passage of a columnar vortex "broadside" through a shock is investigated. The vortex is decomposed (by Fourier transform) into plane sinusoidal shear waves disposed with radial symmetry. The plane sound waves produced by each shear wave-shock interaction, known from previous work, are recombined in the Fourier integral. The waves possess an envelope that is essentially a growing cylindrical sound wave, partly cut off by the shock. The sound wave is centered at the transmitted (and modified) vortex and attenuates inversely as the square root of the growing radius. The strength varies smoothly around the arc, from compression at one shock intersection to rarefaction at the other shock intersection. Comparison is made with results of a shock-

tube investigation and heuristic theory by Hollingsworth and Richards in England.

From authors' summary by N. Tetervin, USA

333. Carstensen, E. L., Measurement of dispersion of velocity of sound in liquids, *J. acoust. Soc. Amer.* **26,** 5, 858-861, Sept. 1954.

334. Skudrzyk, E., Scattering in an inhomogeneous medium, *J. acoust. Soc. Amer.* **29,** 1, 50-60, Jan. 1957.

Applications are made of the integral expressions for pressure derived by Rayleigh, and of the space-averaged intensity derived by Pekeris; these (essentially Rayleigh-Gans-Born approximations) apply for a medium containing slight inhomogeneities, i.e., of relative index of refraction small compared to unity and of small optical path difference. Using exponential and Gaussian space-autocorrelation functions, approximations are obtained for the scattered intensity, and the average pressure fluctuations. The variation of scattering with range, frequency, and patch size, and space correlations in fluctuations are also discussed.

V. Twersky, USA

335. Cornelissen, J., and Waterman, H. I., Prediction of the velocity of sound in mineral oil fractions from kinematic viscosity, refractive index and density, *Fuel* **36,** 2, 130-134, Apr. 1957.

A method of predicting the velocity of sound in mineral oil fractions from kinematic viscosity, refractive index and density is discussed. The method involves the use of a space model with mutually perpendicular coordinates log V, n_D and d_4, in which surfaces of equal values of the velocity of sound can be constructed.

From authors' summary

336. Hikata, A., and Truell, R., Frequency dependence of ultrasonic attenuation and velocity on plastic deformation, *J. appl. Phys.* **28,** 5, 522-523, May 1957.

The dependence of ultrasonic attenuation and velocity on plastic deformation in 2S aluminum is compared at two frequencies, five and ten megacycles, and the comparison shows agreement as regards frequency dependence with what one can expect from dislocation damping theory.

From authors' summary

337. Young, J. E., Correlation functions for noise fields, *J. acoust. Soc. Amer.* **26,** 5, 788-789, Sept. 1954.

Ballistics, Detonics (Explosions)

(See Revs. 249, 273)

Soil Mechanics, Seepage

(See also Revs. 122, 155, 156, 349)

Book—338. Schwab, G. O., Frevert, R. K., Barnes, K. K., and Edminster, T. W., Elementary soil and water engineering, New York, John Wiley & Sons, Inc., 1957, viii + 296 pp. $6.25.

This is a valuable textbook for students and laboratories in agriculture and related fields. Engineering phases of soil and water conservation are emphasized from viewpoint of agronomic, economic, and other problems. Main subjects are: surveying and its application to field problems, design and layout of conservation practice; use and adjustment of surveying equipment; discussion of various phases of conservation engineering problems on the farm and pertaining details and laboratory problems; illustration and standardization of recording field data; laboratory problems developed at Iowa State College and Ohio State University; public land surveys, runoff, soil erosion, surface drainage; wind erosion control and land clearing. Credit for valuable suggestions are given to Craig Beer, M. W. Bittinger, Howard P. Johnson, David B. Palmer. Book is amply illustrated, and each chapter contains a great number of references and problems (with added solutions).

J. J. Polivka, USA

339. Polz, K., The vibrating foundation in dynamically loaded systems (in German), *Bautechnik* **33,** 6, 185-190, June 1956.

Author investigates the behavior of soil supporting the foundation of vibrating machinery. Modes of vibration considered include vertical and horizontal vibration, tilting around a horizontal axis and torsion around a vertical axis.

Equilibrium requirements lead to the wave equation, which is solved in terms of an arbitrary function describing a spherical wave diverging from the foundation. With each mode of vibration of the supported machinery there is associated an ordinary differential equation with boundary conditions determining the wave function.

Author derives formulas for stresses and deformations in the supporting soil. For periodically vibrating machines, steady-state and transient solutions are given. Magnitudes and phases of ratios of dynamic to static deformations are presented graphically. Stresses and deformations due to sudden impact are also described.

Lack of detailed references to the literature is a serious handicap.

P. M. Treuenfels, USA

340. Bhatia, H. S., and Amanullah, N., Foundation design based on bearing capacity and settlement analysis of soil, *J. Instn. Engrs., India* **37,** 5, part 1, 429-440, Jan. 1957.

341. Peltier, R., Deformation of roads under strain (in French), *Construction* **11,** 9, 295-302, Sept. 1956.

342. Gubenko, T. P., Lukin, V. I., Bardachevsky, V. T., and Vlasenko, N. V., Problems of automation of well drilling processes (in Russian), Nauch. Sb. Lvovsk. politekhn. in-ta. posvyashch. 33C-letiya vossoedineniya Ukrainys Rossiei, Lvov, Izd-vo un-ta, 123-124, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5007.

A description is given of a model for investigating processes of automatic control of the drive of a column of boring tubes. The distributed parameters of the column are reproduced with the aid of a chain of several successively connected elements having concentrated parameters. The elastic properties, the mass of tubes and their friction against the wall of the well are imitated by elastic sleeves, massive flywheels, and hydraulic appliances filled with a clay solution.

An analysis is given of the system of automatic supply of the drilling instrument.

There are a number of inaccurate definitions and conclusions in the paper.

S. I. Bernshtein, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Micromeritics

(See also Revs. 14, 338, 342)

343. Russell, W. L., A new instrument for measuring bulk and grain volumes, *J. Petr. Technol.* **9,** 7, 51-53, July 1957.

A new instrument for measuring bulk and grain volumes is described and compared in accuracy with two modifications of Nutting's method. All three methods are reasonably fast, and in all three the probable error in the determinations of bulk volume can be kept down to about 0.1 to 0.2%.

From author's summary

344. Marathe, B. R., and Joglekar, G. D., Measurement of the specific surface and covering capacity of graphite powders, *J. sci. indust. Res., India* **16,** 1, 23–28, Jan. 1957.

The covering capacity, particle thickness, and specific surface of natural graphite samples from four different sources and in three different particle size ranges, generally used in crucible manufacture, have been determined. Particle thickness calculated by the "covering capacity" method has been compared with that obtained by measuring the particle dimensions with a microscope. Acicularity and isoproportionality coefficients for the samples from the four different sources, a knowledge of which may be useful in understanding the breakage phenomenon of graphites, have been evaluated. The possibility of identifying the source of the ore from specific surface measurements is indicated.

From authors' summary

345. Moltini, E., Screening analysis powder particle analysis: Particle-size determination by screen analysis (in Italian), *Industria Mineraria, Rome* **7,** 771–784, 1956.

Various types of screen-size successions are discussed: arithmetic and geometric series, the latter with various proportionality factors, as square root 2, and fourth root 2, the influence of wire sizes and of the space between the wires. Specific screen-size successions are then considered, namely: (a) The "Tyler Standard Screen Scale" (developed by the firm of W. S. Tyler Co., Cleveland) based on the work of Rittinger and Richards, which is used in USA, South Africa, Italy, France, USSR, and other countries. This is based on the factor of square root 2, i.e., 1.414, and on the basic "mesh" of 200 per inch and wire size 0.053-mm diam.

(b) The U. S. Bureau of Standards (USBS), and Amer. Soc. Testing Materials scale (ASTM), also based on the square root 2, or fourth root 2 factor, having a basic mesh of 18, with an aperture of 1 mm.

(c) The DIN 1171 scale used in Germany and in other countries; in this the screen is defined either by the size of aperture or the number of meshes per linear centimeter; the factor is not constant but varies between 1.11 and 1.5.

(d) The British Engineering Standards Association scale (BESA), used in England, South Africa and Australia, having a base of 200 mesh and a factor of fourth root 2 (1.189).

(e) The Association Francaise de Normalization series (AFNOR), having a base of 0.40 mm aperture and a factor of tenth root of 10 (1.2589) (or for closer gradations twentieth or fortieth root of 10). The series AFNOR corresponds also to the International Standards Organization (ISO) series.

(f) The UNI 2331 series adopted in Italy, corresponding to the AFNOR series, but with an intermediate size interposed between each member of the tenth root of 10 series.

Each of these series is represented in a table and also in a nomogram. The method of carrying out the analysis is described; the velocity of sieving, the influence of humidity, calibration, the methods of representation (arithmetic and logarithmic abscissas and the Rosin-Rammler-Bennet (RRB) coordinates) are discussed. It is stated that the RRB coordinate system has important advantages and is being accepted by several countries. In Germany it is standarized as DIN 4190.

K. J. De Juhasz, Germany

346. Daniels, T. C., Investigation of a vortex air cleaner, *Engineer, Lond.* **203,** 5276, 358–362, Mar. 1957.

The straight flow through a cylindrical tube is used to study the efficiency of separation by the superposition of a concentric vortex. The concentration of solids at the wall follows theoretical predictions. Actual separation of the particles is hampered by rebounding at the wall. Author prevents this by wetting the walls, and proposes wetting as a practically usable method.

H. A. Einstein, USA

347. Mansur, C. I., Laboratory and in-situ permeability of sand, *Proc. Amer. Soc. civ. Engrs.* **83,** SM 1 (*J. Soil Mech. Found. Div.*), Pap. 1142, 21 pp., Jan. 1957.

Seepage analyses and design of seepage-control measures require a reasonably accurate knowledge of the coefficient of permeability of the strata of sand involved. The results of laboratory tests on remolded sand samples are compared with permeabilities obtained from field pumping tests in which the permeabilities of individual sand strata were determined from drawdown curves and flow from the strata as measured with a special well meter.

From author's summary

348. Lambert, R. F., Side branch insertion loss in a moving medium, *J. acoust. Soc. Amer.* **28,** 6, 1059–1063, Nov. 1956.

Studies of the insertion loss of a side branch resonant filter in moving air reveal that nonlinear excitation of the resonator and turbulence may influence the measured characteristic. These effects occur at relatively low Mach numbers for particular flow geometry patterns. The insertion loss is found to be destroyed for sufficiently high flow velocities. An interpretation of insertion loss values as averaged over a finite band of frequencies is also given some attention.

From author's summary

349. Stutsman, L. F., and Thodos, G., Frontal drive production mechanisms—a new method for calculating the displacing fluid saturation at breakthrough, *J. Petr. Technol.* **9,** 4, 67–69, Apr. 1957.

A variation in the Leverett-Buckley [*Trans. AIME* **146,** p. 107, 1942] method is described and illustrated by an example of frontal flood advance in a water injection case. For cases involving displacement of gas, authors claim their method is more conveniently used than that of Leverett-Buckley.

S. R. Faris, USA

Geophysics, Meteorology, Oceanography

(See also Revs. 197, 243, 291, 297)

350. Burdecki, F., A study of the heat field of the atmosphere, *J. Meteor.* **14,** 3, 206–234, June 1957.

In this lengthy and elaborate paper, fundamental aspects of the heat balance of the atmosphere and of the atmospheric heat circulation are investigated. Paper was essentially based on tables and charts of the British Meteorological Office (M.O. 23, 24 charts, mimeogr. 1951) and is the final one following *Notos* **4,** 192–203, 1955. The distribution of heat in different layers and in particular months is studied, and analytic expressions for the seasonal fluctuations of the heat distribution in the atmospheric layers are given. The annual heat turnover for different atmospheric layers and latitudinal zones is computed. New concepts, namely "heat potentials," "pseudo-constant of circulation," and "coefficients of circulation" are introduced and explained. The approximate values of the circulation constant and of mean zonal coefficients are computed. The so-called "Schmidt paradox" is briefly discussed, and it is shown that the coefficients of circulation must be taken into account in every meteorological consideration. A revised concept of atmospheric circulation and a definition of the intensity of atmospheric circulation are deduced from the potential analysis of the thermal field. An attempt is made to formulate general characteristics of the fluctuating thermal field of the atmosphere.

H. Arakawa, Japan

351. Tank, W. G., The use of large-scale parameters in small-scale diffusion studies, *Bull. Amer. meteor. Soc.* **38,** 1, part 1, 6–12, Jan. 1957.

Using Ekman's spiral equation, author expresses the eddy diffusivity K in terms of the angle between the surface and geostrophic wind and the height at which the wind direction be-

comes geostrophic. This value is then used in Robert's diffusion equation to study the concentration change in a cloud of gas released from an explosion in the open. Comparison is made between predicted and actual values in seven experiments. Agreement is fairly good, and author discusses at some length the limitations of his simplified theory.

Reviewer would be interested to see a more comprehensive theory developed using the extensive data obtained from the experiments. R. P. Pearce, Scotland

Lubrication; Bearings; Wear

(See Rev. 289)

Marine Engineering Problems

(See also Rev. 61)

352. Todd, F. H., Skin friction resistance of ships, *J. Ship Res.* **1,** 2, 3-12, July 1957.

The fundamental problem in ship model testing is that of extrapolating model resistance data to prototype values. This paper is essentially a review of present methods in use, a discussion of the direction of current research, and an exploration into the possibility of an agreement on a common formulation of procedure relevant to resistance extrapolation.

At present the Froude assumption for total resistance has been agreed upon as the basis for all published work on ship power predictions by the International Towing Tank Committee. The coefficients are determined by one of two methods, one using Froude friction coefficients, and the other the Schoenherr resistance curve adopted by the American Towing Tank Conference (ATTC) in 1947.

Variations in hull form, eddy formation, flow separation, and hull roughness are at present overwhelming obstacles to the search for a single friction line in the extrapolation problem. Despite the known limitations of the Froude assumption, the ATTC at its meeting in 1956 resolved to continue the use of the 1947 ATTC line until the results of current research provide a better insight into this vastly complicated problem. A similar view has been taken by the Taylor Model Basin as a result of a careful review of the problem.

Reviewer believes that members in the model testing field as well as ship designers will find Dr. Todd's paper well worth perusal. It takes the problem out of the "forest" and exposes the individual "trees" in lucid style.

C. E. Carver, Jr., USA.

353. Lewis, E. V., A study of midship bending moments in irregular head seas, *J. Ship Res.* **1,** 1, 43-55, Apr. 1957.

In this article an exploratory study on behalf of the S-3 Panel of the Society of Naval Architects and Marine Engineers is reported, in which the statistical characteristics of model bending moments in irregular head seas have been predicted on the basis of the principle of linear superposition of responses to the component waves. It is shown that, for the case of a T2-SE-A1 tanker model, agreement between predicted and observed bending moments in irregular waves is reasonably good. The method is then applied to predicting the trend of bending moments with severity of sea and speed of ship.

From author's summary by C. E. Carver, Jr., USA

354. Inoue, S., On the turning of ships, *Mem. Fac. Engng. Kyushu Univ.* **16,** 2, 110 pp., Dec. 1956.

Author treats the title subject at considerable length. First he introduces airfoil theory as applied in the analysis of the turning of a ship represented to a rough approximation by a rectangular plate of small aspect ratio. Then he develops equations of moment and normal force for ship moving obliquely, ship on even keel, and ship in a given condition of trim. Finally he considers stability of motion and steady turning.

An appreciable amount of mathematical analysis, as well as many curves expressing theoretical and experimental results, is presented. Experimental apparatus is described and a few photographs of turning circle equipment are shown.

There are many references to the theoretical work of Kármán, Munk, Glauert, Prandtl and others as well as to the classical experiments of Weinblum, Davidson, and Schiff.

Much of the work in author's paper seems to have been presented by him previously in Japanese journals of naval architecture. W. H. Hoppmann, USA

355. Troost, L., The pitch distribution of wake-adapted marine propellers, *Shipbuilder* **64,** 589, 264-267, Apr. 1957.

Author reviews the published formulations for the design of wake-adapted propellers and introduces a new formulation for minimum energy loss which includes consideration of the propeller loading. The pitch distribution resulting from the new formulation is compared with previous results and indicates a smaller pitch reduction is required in the high wake area.

Author considers the applicability of his formulation to controllable-pitch propellers. He concludes that by using constant pitch at dead pull ahead the resulting pitch at other ahead conditions will be in general agreement with the formulation. Some loss in backing performance is predicted for this procedure.

J. G. Hill, USA

356. Tachmindji, A. J., and Milam, A. B., The calculation of Goldstein factors for three, four, five and six-bladed propellers, *David W. Taylor Mod. Basin Rep.* 1034, 23 pp., Mar. 1956.

Authors supply tables and diagrams resulting from more accurate calculation of the Goldstein factors for various marine propellers (factors allowing the determination of the distribution of circulation about each blade section, particularly for moderately loaded propellers). The calculations are performed for radii ratios ranging from 0.2 to 0.975, and for advance ratios ranging from 0.166 to 4. The results are compared with Kramer's results.

R. G. A. Spronck, Belgium

357. Schuster, S., Contribution to the problem of a five-bladed ship propeller (in German), *Jahrbuch Schiffbautech. Gesellsch.* **49,** 87-109, 1955.

Author compares the propulsion characteristics and factors of variations of marine propellers with various numbers of blades. Theoretical calculation, model experiment results, and trial data are used for the comparison. Influence of modifications of the stem of ships is discussed. Finally, the five-bladed propeller seems to be a very advantageous solution, provided further measurements corroborate the results obtained, namely regarding ship vibrations. R. G. A. Spronck, Belgium

358. Dickmann, H. E., and Weissinger, J., Contribution to the theory of the Kort system of propulsion (in German), *Jahrbuch Schiffbautech. Gesellsch.* **49,** 253-305, 1955.

The Kort system of propulsion is treated here theoretically, not as a propeller and a ring, but as a single propulsion element, operating like an axial pump.

Author gives a thorough review of the prior theories, and supplies computed and tabulated functions to be used in the correct choice of the best characteristics of the Kort system in practical problems of propulsion. R. G. A. Spronck, Belgium

Books Received for Review

BEKKER, M. G., Theory of land locomotion, Ann Arbor, Michigan, The University of Michigan Press, 1956, x + 519 pp. $12.50.

CANNING, R. G., Installing electronic data processing systems, New York, John Wiley & Sons, 1957, xiii + 193 pp. $6.00.

DIENES, G. J., and VINEYARD, G. H., Radiation effects in solids, Vol. II of Interscience monographs in physics and astronomy, New York, Interscience Publishers, 1957, viii + 226 pp. $6.50.

FLUGGE, W., Statik und Dynamik der Schalen, second revised edition, Berlin, Springer-Verlag, 1957, viii + 286 pp.

FRANKEL, J. P., Principles of the properties of materials, New York, McGraw-Hill Book Co., 1957, xiv + 228 pp. $6.00.

FRAZEE, I., BEDELL, E. L., and VENK, E., edited by, Automotive engines, Chicago, American Technical Society, xiii + 402 pp.

HUBNER, E., Technische Schwingungslehre in ihren Grundzugen, Berlin, Springer-Verlag, 1957, xi + 322 pp.

ROUSE, H., and INCE, S., History of hydraulics, Iowa Institute of Hydraulic Research, State University of Iowa, 1957, xii + 269 pp.

TATON, R., Reason and chance in scientific discovery, New York, Philosophical Library, 1957, 171 pp. $10.00.

WEBER, H. C., and MEISSNER, H. P., Thermodynamics for chemical engineers, second edition, New York, John Wiley & Sons, 1957, vii + 507 pp.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Ackoff, R. L. 12
Agadzhanyan, G. G. 149
Alexander, J. M. 142
Amanullah, N. 340
Andrews, S. J. 292
Argyris, J. H. 81
Arie, M. 267
Arnoff, E. L. 12
Arthur, J. R. 329
Arzhanykh, I. S. 171
Atsumi, A. 82
Babaev, N. N. 57
Babister, A. W. 36
Bair, W. E. 312
Baird, R. B. 96
Ballabh, R. 161
Bardachevsky, V. T. 342
Barnes, K. K. 338
Barta, J. 105
Barton, M. V. 52
Batch, J. M. 305
Batchelor, G. K. 33, 160
Batchelder, G. W. 328
Bauer, F. L. 7
Baum, Q. 248
Bayley, F. J. 162
Becker, E. 222
Beckwith, I. E. 216
Bellman, R. 147
Benington, F. 326
Bevierre, P. 178
Bhatia, H. S. 340
Bhatnagar, P. L. 130
Biggs, J. M. 70
Birkebak, R. 202
Blokh, E. L. 204
Boettner, R. C. 137
Bohmer, J. F. 126
Bolcskei, E. 106
Bond, J. W., Jr. 211
Bonfiglioli, L. 11
Borisenko, A. I. 167
Bradley, J. C. 209
Bradley, P. C. 292
Breklovskikh, L. M. 78
Brooks, W. A., Jr. 89
Brouns, R. C. 96
Brown, E. H. 80
Buchanan, F. E. 14
Buchner, E. 271
Buglia, J. J. 215
Burdecki, F. 350
Burmistrov, E. F. 103
Burr, A. H. 289
Cabot, L. 177
Carlson, R. L. 138
Carstensen, E. L. 333
Cartaino, T. F. 25
Carter, W. J. 207
Cess, R. D. 287
Chakravorty, J. G. 83, 84
Chambre, P. L. 293
Chang, Y. P. 298
Chapman, D. R. 186
Chauvin, L. T. 215
Chawalla, E. 111
Cheers, F. 252
Chibaeff, V. G. 309
Childs, E. C. 155, 156
Churchman, C. W. 12
Clark, J. W. 59
Clerc, B. 255
Cohen, Doris 194
Cohen, N. B. 218
Cole, D. M., Jr. 95
Coleman, R. P. 69
Collis-George, N. 155
Conner, N. W. 154
Cornelissen, J. 335
Corrsin, S. 231
Crabtree, L. F. 237
Crouzet, J. 177
Cunningham, D. M. 56
Daniels, T. C. 346
Davids, N. 75
Davidson, K. S. M. 35
Davies, R. M. 28
Debeauvais, F. 257
Dickman, H. E. 358
Diederich, F. W. 249
di Mauro Pacelli, N. 85
Domm, U. 234
Donaldson, C. 139
Donely, P. 239
Dorrance, W. H. 210
Dreyfus, S. E. 25
Drischler, J. A. 249
Dropkin, D. 289, 290
Duwez, P. 279
Dwyer, O. E. 290
Dyrbye, C. 214
Eckert, E. R. G. 202
Edminster, T. W. 338
Eichelbrenner, E.-A. 226, 227
Einbinder, H. 326
Elder, J. K. 328
Ellison, T. H. 34
Englert, G. W. 217
Eringen, A. C. 60
Erugin, N. P. 4
Etkin, B. 55
Fabri, J. 195
Faget, M. A. 266
Fairall, R. S. 308
Feidt, R. 257
Feingold, A. M. 69
Fentzloff, H. E. 125
Fetting, F. 235
Filin, A. P. 87
Fine, B. 317
Fisher, L. J. 260
Fitch, C. J. 23
Fitswilliams, O. L. L. 68
Foley, D. J. 305
Ford, H. 142
Fraser, D. 244
Frederiksen, E. 191
Freudenthal, A. M. 131
Frevert, R. K. 338
Fryer, T. B. 251
Fuhrke, H. 71
Fung, Y. C. 184
Gadd, G. E. 221
Gardiner, G. M. 327
Gazley, C. 294
Gazley, C., Jr. 295
Gebel, C. 257
Georgian, J. C. 99
Ghosh, B. 313
Ghosh, M. 77
Gibson, F. W. 261
Gillies, A. W. 51, 54
Goldenberg, S. A. 323
Goldfarb, L. S. 40
Goldsmith, W. 56
Gorling, P. 303
Goroshchenko, L. 243
Graham, E. W. 201
Graham, R. D. 302
Grant, W. L. 299
Grassin, H. 315
Green, H. L. 30
Green, N. B. 122
Griffith, G. E. 89
Grimble, R. E. 166
Grobbelaar, C. 132
Gronau, K.-H. 240
Grosh, R. J. 287
Gubenko, T. P. 342
Hagel, W. C. 59
Gustafson, F. B. 253
Hagy, H. E. 165
Haines, A. B. 268
Hanawalt, A. J. 206
Hartley, D. E. 268
Hartnett, J. P. 202
Hawk, A. C. 242
Hazard, H. R. 326
Heaps, N. S. 90
Heebink, B. G. 116
Hikata, A. 336
Hill, R. 26
Hirschfelder, J. O. 275
Hoe, R. J. 290
Hoff, H. 135
Hoffman, E. L. 260
Holmes, J. W. 155
Holzweissig, F. 64
Hornig, D. F. 187
Hsu, Y. Y. 306
Hufnagel, S. 277
Hurwitz, H., Jr. 10
Inoue, S. 354
Ivanov, I. D. 78
Iwasaki, M. 185
Jahn, R. G. 188
Jacket, H. S. 304
Jaoul, B. 143
Jasper, N. H. 62
Javorsky, P. 65
Joglekar, G. D. 344
Johnson, W. 140, 141
Jones, R T. 196
Jousserandot, P.-Q. 238
Juhasz, S. 307
Kalman, R. E. 37
Kammerer, C. 181
Kappus, R. 255
Katys, G. P. 18, 19, 22
Kawamura, R. 182
Keller, A. 136
Kern, D. Q. 301
Kestin, J. 9, 272
Kettelle, J. D. 326
Khitrina, L. N. 323
Kholmianskii, M. M. 101
Klein, B. 110
Klein, H. 245
Klein, M. L. 13
Klier, E. 65
Klotter, K. 38
Komatsu, S. 117
Konishi, I. 117
Kopineck, H.-J. 135
Kotanchik, J. N. 97
Kreiter, M. R. 305
Krzywoblocki, M. Z. 200
Kubota, T. 208
Kuehn, D. M. 186
Kumar, S. 75
Kuo, Y. H. 236
Kurz, P. F. 318
Kuske, A. 93
Lafon, R. 319
Lakshmana Rao, S. K. 130
Lambert, R. F. 348
Lambertson, T. J. 311
Lamson, P. 233
Landry, B. 326
Lange, A. 45
Lankford, W. T. 138
Lane, W. R. 30
Larson, H. K. 186
Lebedev, V. I. 6
LeCain, G. H. 139
Leeman, E. R. 132
Le Grives, E. 195
Leonard, A. S. 175
Lessing, H. C. 251
LeTourneau, B. W. 166
Levey, H. C. 179, 246
Levy, A. 326
Levy, S. 307
Lewis, E. V. 353
Lewis, T. G., Jr. 145
Lichtenheldt, W. 16

(Continued on outside back cover)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Lichty, L. C.....312
Liddell, H. F.....172
Lighthill, M. J.....32
Lindquist, D. C.....269
Ling, C. B.....79
Litvin-Sedoi, M. Z.....44
Long, L. W.....154
Lorenz, I. M.....1
Louw, J. M.....70
Lovikov, P. F.....174
Lukin, V. I.....342
Lykoudis, P. S.....286
Macaulay, R. W.....327
MacDonald, R. J.....138
Mader, F. W.....100
Makofski, R. A.....205
Malkin, I. G.....2
Mansur, C. I.....347
Manzheron, D. I.....21
Mar, J. W.....88
Marathe, B. R.....344
Marchi, E. 148, 213
Markstein, G. H.....321
Martin, A. I.....164
Martin, A. R.....120
Martin, J. C.....219
Masson, D. J.....294
Mayorcas, R. 325
McEwen, L. H.....305
McGoldrick, R. T.....61
McWithey, R. R.....66
Mead, M. H.....251
Mees, L. A. A.....123
Mickelsen, W. R.....320
Miesse, C. C.....326
Milam, A. B.....356
Miles, J. W.....256
Milwitzky, B. 269
Mitchell, A. R.....159
Mittelmann, G. 94
Moltini, E. 345
Montague, K. E.....14
Morgan, H. C.....13
Morkovin, M. V.....262
Morton, B. R.....297
Moskvin, D. S.....43
Mott, N. F.....27
Mucha, E. 46
Murin, G. A.....150
Murray, J. D.....159
Neumark, S. 250
Neumüller, M. 151
Nicolas, J. 193
Noble, M. D.....14
Nokhratyan, K. A.....331
Noll, W. 53
Norell, R. G.....210
Odelsky, E. Kh.....168
Odman, S. T. A.....119
O'Hara, F. 254
Olson, D. R.....312
Orning, A. A.....313
Oudart, A. 226, 227
Pagel, H. J.....73
Palmer, H. B.....187
Palmer, K. N.....330
Parmakian, J. 212
Patraulea. N. N.....157
Paulon, J. 195
Peltier, R. 341
Pennington, R. H.....147
Persen, L. N.....9
Peters, E. H. J.....49
Petrasovits, G. 124
Petrov, V. V.....41
Pilcher, J. M.....326
Pogosov, A. A.....5
Polz, K. 339
Pospelov, G. S.....42
Potter, D. M.....269
Powell, R. D., Jr.....247
Pride, R. A.....108
Putnam, A. A.....326
Rakhamonovich, A. N....176
Ralls, J. A.....95
Ram, G. S.....332
Raman, C. V.....276
Ramsen, J. A.....173
Rappeneau, J. 315
Ray, K. 77
Reeves, E. I.....47
Reshotko, E. 216
Ribner, H. S.....332
Riddell, F. R.....203
Ries, H. C.....270
Ritland, H. N.....165
Riviere, M. 325
Rivlin, R. S.....230
Roarty, J. D.....304
Robacker, J. T.....183
Robertson, W. D.....137
Robinson, A. 72
Rose, P. H.....203
Rosenblat, S. 169
Roth, W. 134
Rouse, H. 267
Roy, S. K.....91
Ruddle, R. W.....282
Rudnicki, J. M.....114
Ruhl, K. 73
Russell, W. L.....343
Sackmann, M. L.-A.....257
Saffman, P. G.....153
Sagot, J. 259
Saito, H. 182
Sakurai, A. 189
Sandahl, C. A.....266
Sanger-Bredt, I.....273
Sattler, K. 107
Schlichting, H. 229
Schmidt, C. M.....206
Schmit, L. A.....88
Schmitz, G. 265
Schneider, P. J.....285
Schramm, K. H.....316
Schuh, H. 264
Schuster, S. 357
Schwab, G. O.....338
Schwarz, W. H.....231
Sedney, R. 192
Seibold, W. 197
Serizawa, Y. 284
Shearer, J. L.....48
Shield, R. T.....128
Sinha, K. D. P.....225
Sklyansky, A. L.....24
Skudrzyk, E. 334
Smiley, R. F.....67
Smith, F. B.....291
Smith, W. D.....329
Soroka, W. W.....58
Spencer, H. M.....274
Squire, H. B.....29
Squire, L. C.....220
Staab, F. 324
Stauffer, W. 136
Steiner, H. 111
Stout, T. M.....39
Strasberg, M. 152
Strass, H. K.....89
Strobel, R. 271
Struble, R. A.....102
Stutsman, L. F.....349
Suer, H. S.....70
Sutton, G. W.....92
Suzuki, M. 98
Swanson, A. G.....215
Swida, W. 86
Tache, J. 63
Tachmindji, A. J.....356
Takizawa, E. T.....129
Tank, W. G.....351
Tapscott, R. J.....253
Tarkhanov, K. S.....20
Test, F. L.....288
Thodos, G. 349
Thomas, R. E.....326
Thomson, R. G.....66
Thomson, W. T.....52
Thurston, G. A.....109
Tocher, D. 76
Todd, F. H.....352
Tolle, O. 17
Tomilov, E. D.....163
Touloukian, Y. S.....286
Townsend, A. A.....33
Traugott, S. C.....232
Trimpi, R. L.....190, 218
Troost, L. 355
Troshin, Ya. K.....314
Truckenbrodt, E. ...224, 241
Truell, R. 336
Truitt, R. W.....158
Turner, P. E.....263
Tyler, R. D.....199
Umetsu, K. 185
Ursell, F. 31
Uvarov, A. P.....170
Van Dyke, M. D.....198
van Spiegel, E.....310
Vishik, M. I.....3
Vlasenko, N. V.....342
Volterra, E. 74
Vorovich, I. I.....104
Vosteen, L. F.....66
Walther, L. 50
Wang, H. E.....272
Waterman, H. I.....335
Weber, H. E.....223
Weber, J. 242
Wechmann, A. 146
Weissinger, J. 358
Weller, A. E.....326
Westwater, J. W.....306
Wheelon, A. D.....183
Whillier, A. 280
Wicka, B. 118
Wigle, B. M.....62
Wilkinson, R. G.....144
Williams, F. K.....13
Willm, G. 278
Wilson, E. D.....270
Wilson, J. C.....283
Winter, K. G.....264
Wolter, H. 258
Woods, L. C.....169
Wootten, N. W.....172
Wright, P. J. F.....133
Wright, W. 121
Wu, C.-H. 180
Yeh, H. 232
Yellott, J. I.....281
Young, A. D.....250
Young, J. E.....337
Yu, Y.-Y. 8
Zachmanoglou, E. C.....74
Zender, G. W.....108
Zerbe, J. E.....166, 304
Zernik, W. 296
Zinzen, A. 322
Zuber, N. 300
Zuk, W. 112
Zweifel, P. F.....10
Zysina-Molozhen, L. M...228